A NEW PERSPECTIVE IN THE ETIOLOGY, TREATMENT, PREVENTION AND PREDICTION OF SPACE MOTION SICKNESS

THESIS

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AFIT/GSO/ENG/88D-2

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The research analyzed heart rate, respiration, gastro-intestinal activity, and brain wave activity. The research found an increase in mean heart rates, mean respiration intake volume, and electrosplanchnogram root mean square voltages during motion sickness. Root mean square voltages of subdelta-delta (.05-1 HZ) electroencephalogram (EEG) activity increased in subjects that were least susceptible to motion sickness while subjects that were highly susceptible to motion sickness had insignificant subdelta-delta EEG activity.

Motion sickness models were developed using the Barron Associates' Abductive Reasoning Mechanism (ARM) software. Motion sickness prediction models were developed using the ARM software and linear regression.

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THESIS

Presented to the Faculty of School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Masters of Science in Space Operations

Rogelio Morales, Jr., B.S., B.A.
Captain, USAF

December, 1988

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Preface

This research studied the therapeutic efficacy of phenytoin (dilantin) in motion sickness. It also developed a mathematical model relating an individual's level of motion sickness with the physiological data collected on the individual. Finally, a mathematical prediction model for motion sickness was developed.

I wish to thank the many people who supported my efforts during this project. First, I would like to start with the people at AFIT. I thank my advisor Dr. Matthew Kabrisky for his unlimited patience and unfailing source of encouragement. I thank Dr. William Chelen for sharing his medical and electrical engineering expertise. I thank Mr. Durham for providing laboratory and equipment support. I also wish to thank Mr. Dan Zambon of the Information Sciences Laboratory for providing the computer systems to use the Abductive Reasoning Mechanism software. I would also like to thank Captain Russel Smith for his laboratory support this summer. And a special thanks to my thesis partner, Captain Mark Scott.

Second, I would like to thank the motion sickness researchers at Johnson Space Flight Center and at Ames Research Center.

Finally, I thank my wife Catherine and my children Roy, Daniel, Chantel, and Michael for their understanding and their support for the past 18 months.

Rogelio (Roy) Morales, Jr.

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Seven male subjects were given the drug phenytoin (dilantin) in a double blind, placebo-controlled crossover experiment. Subjects were rotated in a motion stimulus chair while several of their physiological parameters were measured. Subjects treated with dilantin were found to have a greater tolerance to motion sickness than when they were treated with a placebo. Also, dilantin did not affect the physical performance and cognitive skills of the subjects.

The research analyzed heart rate, respiration, gastro-intestinal activity, and brain wave activity. The research found an increase in mean heart rates, mean respiration intake volume, and electrosplanchnogram root mean square voltages during motion sickness. Root mean square voltages of subdelta-delta (.05-1 HZ) electroencephalogram (EEG) activity increased in subjects that were least susceptible to motion sickness while subjects that were highly susceptible to motion sickness had insignificant subdelta-delta EEG activity.

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A NEW PERSPECTIVE IN THE ETIOLOGY, TREATMENT, PREVENTION AND PREDICTION OF SPACE MOTION SICKNESS

I. Introduction

Background

The United States space program has undergone an extensive restructuring since the Space Shuttle accident. Additionally, the U.S. has renewed its commitment to an American presence in space. This commitment is evident by the military's, NASA's and private industry's eagerness to return to space. All three groups are planning manned missions into space. These new plans include the Strategic Defense Initiative, National Aerospace Plane, the Space Station, the Industrial Space Facility, a mission back to the moon, a colony on the moon and a mission to Mars. A major biomedical concern for all these missions is a form of motion sickness known as space motion sickness (SMS).

Motion Sickness. Before discussing space motion sickness, an explanation of motion sickness is provided. Motion sickness is a generic term which includes sea sickness, air sickness, car sickness, space sickness, simulator sickness, cinerama sickness, microfiche sickness, etc. Each condition is a various form of the malady named after the environment or vehicle. Generally, motion sickness is induced by actual world motion; however, motion sickness can also be induced by perceived motion. Simulator sickness, cinerama sickness and microfiche sickness are examples of motion sickness in the absence of physical motion. Although motion sickness can be considered to be a disease it is also a normal response to an abnormal

environment. In fact, the absence of symptoms during motion stimulus may indicate a deficient vestibular system (12:468).

Motion sickness is a physiological dysfunction induced by real or perceived motion stimulus and "characterized primarily by nausea, pallor, cold sweating and vomiting" (12:468). Other possible symptoms include salivation, feeling of warmth, light-headediness, depression or apathy, yawning and drowsiness, belching, headache, and occasionally hyperventilation (12:470).

The currently accepted explanation for motion sickness is the sensory conflict theory (12:474-481). The theory suggests that the brain is constantly receiving information from the visual system and from the vestibular system on the position and movement of the body (12:476). Sensors in muscles of the neck, arms, legs, and other parts of the body also provide the brain with positioning data known as proprioceptive information (2:53). Hence, motion sickness can occur when the brain perceives these various signals to be in conflict compared to the normal motion cues (20:309-310,323).

Space Motion Sickness. As mentioned earlier, space motion sickness is a specific form of motion sickness and is "characterized by increased sensitivity to motion and head movements, headache, malaise, lethargy, stomach awareness, loss of appetite, nausea, and episodic vomiting" (25:448). However, unlike terrerstrial motion sickness, space motion sickness rarely induces pallor and sweat (41:3).

In 1982, Lackner and Graybiel studied the effect of motion sickness in both microgravity and macrogravity (18). Their data suggest that space motion sickness is a result of the brain receiving conflicting information from the vestibular system and the otolithic system (18:175). However, their data also point out that motion

sickness is enhanced when the eyes are opened and the sight of the surroundings is permitted (18:173). These results agree with the actual occurrences of space motion sickness during both United States and Soviet Union spaceflight missions. Data from past U.S. and Soviet Union space missions suggest that space motion sickness occurs more frequently when astronauts and cosmonauts have increased movement capability, greater exterior vision and/or fewer internal visual orientation cues to rely on (23:36-1).

Justification

Space motion sickness is a very expensive disease. According to Dr. Patricia Cowings, "Finding a solution to this biomedical problem has become a very high priority goal of the manned space-flight program because of its potential impact on crew safety, comfort and operational efficiency during Shuttle missions" (10:3). Planned crew activities are disrupted when space motion sickness threatens crew safety, crew operations and crew comfort. Consequently, the loss of valuable crew time has cost the space program approximately $10 million per Shuttle flight (37). To date, space motion sickness has not claimed the lives of any astronauts, but space motion sickness has affected both crew comfort and crew operations since the Apollo missions (23:36-1).

Crew Safety. Space motion sickness is a potential danger to susceptible astronauts. Astronauts suffering from space motion sickness are prohibited from performing extra vehicular activities (EVAs). An EVA is a very complex and dangerous activity that requires 100 percent of the astronaut's mental and physical ability. A degradation in health, such as headaches, malaise, lethargy or nausea,

increases the danger of an already dangerous situation. Furthermore, astronauts would probably asphyxiate from their own vomit if emesis occured in their space suits (37). Even astronauts suffering from a mild case of space motion sickness could be in danger during an EVA because emesis can occur in space suddenly and without any warning (38). NASA flight planners postponed planned EVAs for both Apollo 9 and STS-5 because crew members were suffering from space motion sickness (23:36-5). NASA flight controllers can reschedule or cancel planned EVAs if astronauts become space sick; however, there is no contingency plan to cover a mission scenario in which a contingency EVA for either the orbiter or payload must be performed and the astronauts are suffering from space motion sickness.

Operations. Space motion sickness, one component of space adaptation syndrome (SAS), "is an operationally relevant biomedical problem for manned space flight" (23:36-1). In 1984, Homick, Reschke and Vanderploeg reported, "on the basis of past experience, it is clear that space adaptation syndrome presents a potential threat to the well-being and optimal operational performance of space flight members" (23:36-1). The Homick, Reschke and Vanderploeg research also reported that space motion sickness usually developed within the first 36 hours and "gradually diminished between approximately 48-96 hours" into the mission (23:36-4). According to Cowings, "The earliest recorded episode began within only seven minutes of orbit insertion" (10:2). In 1988, Davis, Vanderploeg, Santy, Jennings and Stewart, reported that 71 percent of the crew members of the first twenty-four Space Shuttle missions reported space motion sickness symptoms (25:448). According to Davis, Vanderploeg, Santy, Jennings and Stewart, "There were 26 mild cases (30%), 20 moderate (24%), and 11 severe (13%)" (25:449). According to the NASA space

motion sickness grading criteria (Figure 1), almost half of the 71 percent of space motion sickness cases impacted operations (25:449). Also, according to the space motion sickness grading criteria, even a mild case of space motion sickness may produce retching or vomiting and symptoms may last as long as 48 hours (25:449). It is clear that such a disease could potentially jeopardize the success of DOD Inertial Upper Stage missions, free flyer missions (e.g., Air Force Program 888) and sortie missions (e.g., Air Force Program 675 or STARLAB).

Space Motion Sickness
Grading Criteria

None (0): No signs or symptoms reported with the exception of mild transient headache or mild decreased appetite.

Mild (1): One to several symptoms of a mild nature; may be transient and only brought on as the result of head movements; no operational impact; may include single episode of retching or vomiting; all symptoms resolved in 36-48 hours

Moderate (2): Several symptoms of a relatively persistent nature which may wax and wane; loss of appetite; general malaise, lethargy and epigastric discomfort may be most dominant symptoms; includes no more than two episodes of vomiting; minimal operational impact, all symptoms resolved in 72 hours.

Severe (3): Several symptoms of a relatively persistent nature that may wax and wane; in addition to loss of appetite and stomach discomfort, malaise and/or lethargy are pronounced; strong desire not to move head; includes more than two episodes of vomiting;significant performance decrement may be apparent; symptoms may persist beyond 72 hours.

Figure 1 Space Motion Sickness Grading Criteria (25:449)

Comfort. The space motion sickness symptoms reported by astronauts of the first nine Space Shuttle missions are found in Table 1. These space motion sickness symptoms - anorexia, headache, malaise, lethargy, general stomach discomfort and vomiting - continued to be reported after STS 9 (23:36-4). In severe cases, these "symptoms may persist beyond 72 hours" (25:449). Generally, antimotion sickness medication is used to treat space motion sickness. The Flight Data File Medical Checklist (Figures 2-5) provides the crewmembers the inflight instructions on how to treat space motion sickness (35). Unfortunately, anti-motion sickness medication has had little success in preventing SMS (23:36-6). Consequently, sick crew members must continue to perform normal operations under SMS discomfort.

To reiterate, planned crew activities are disrupted when SMS threatens crew safety, crew operations and crew comfort. SMS has had a major impact on planned crew activities on at least four U.S. space missions. According to Homick, Reschke and Vanderploeg:

> A planned extra vehicular activity (EVA) on Apollo 9 was postponed one day in order to allow the crewmember scheduled to do the EVA an opportunity to fully recover from symptoms. The crew of the Skylab mission went into a "powered-down" mode (i.e. reduced their workload) during approximately the first 36 hours of flight because of SAS symptomatology. A scheduled light workload day was traded with a busy work load day to allow the crew of the STS-3 mission to overcome symptoms. Lastly, a planned EVA on STS-5 was postponed one day to ensure that an affected crewmember was fully recovered from symptoms of SAS. (23:36-5)

Homick, Reschke, and Vanderploeg also noted that the crew activity changes, up to STS-9, did not "impact on the successful accomplishment of mission objective" (23:36-5). On the other hand, the Davis, Vanderploeg, Santy, Jennings and Stewart

Table 1 STS 1-9 Space Motion Sickness Symptoms (23)

SMS SYMPTOMS

SYMPTOM	PERCENT OCCURENCE
Nausea	25.0
Abdominal Fullness/Discomfort	17.0
Vomiting	42.0
Anorexia	40.0
Lethargy	40.0
Malaise	43.0
Headache	45.0
Pallor	5.0

research on space motion sickness during twenty-four Space Shuttle flights implies that almost half of the reported cases of SMS impacted operations (25:449).

With the projected increase in manned space flight it is important to develop a method for screening crews for SMS susceptibility and/or develop a cure for SMS. Currently, there are two popular treatments for space motion sickness: therapeutic agents (e.g. scopolamine and promethazine) and psychological techniques (e.g. biofeedback, desensization and autogenic therapy). Three different methods/models have been used to predict space motion sickness: linear discriminate analysis, a logistic model and composite information method (41). According to Dr. Harm, "our success in predicting and eliminating motion and space motion sickness has been limited", and "It is time to step back, look at the problems from new perspectives, and adopt a new research approach" (21:43).

MOTION SICKNESS

Symptoms: Headache, sleepiness, lethargy, stomach awareness, decreased appetite, flushed feeling, 'tumbling gyros' with head movements, excess salivation, nausea, vomiting

Treatment - GENERAL

1 Rest
2 Extra fluids, bland diet as able
3 Move slowly; avoid head movements

Treatment - MEDICATIONS

1 **Mild Case**-No vomiting, mild nausea
MBK (blue) Anti-motion Sickness Medication
Scop/dex half (D2-6) or full (D2-9) strength
Dose: 1 capsule every 6 hr

2 **Moderate Case**-Nausea, some vomiting
NOTE
DO NOT TAKE PHENERGAN OR COMPAZINE WITHIN 6 HR OF TAKING SCOP/DEX

MBK (blue) Anti-Nausea, Anti-Vomiting Drugs
Phenergan Suppository (D2-2)
Dose: 1 every 12 hr as needed
-OR-
Compazine Suppository (D2-8)
Dose:1 every 12 hr as needed

3 **Severe Case**-Severe nausea, vomiting, fatigue, inability to eat
EMK (red) Anti-Nausea, Anti-Vomiting Drugs - Injectable
NOTE
Call Surgeon before using injectable drugs; see IM Injection Technique, pp.4-7

Phenergan (A2-16,17)
Dose: Inject 1/2 to 1 cc IM
-OR-
Compazine (A2-13,14,15)
Dose: Inject 1/2 to 1 ampule IM

4-18 MED/ALL/BAS J

Figure 2 Inflight SMS Treatment Checklist (35:4-18)

COMPAZINE - For control of severe nausea and vomiting.

DO NOT USE WITHIN 6 HR OF TAKING SCOP/DEX.
DO NOT USE WITH *PHENERGAN

Warning: May cause spasms of head and neck muscles, inability to concentrate, sedation, and can intensify the effects of other drugs (narcotics) that depress the central nervous system. (See general warning about drug interactions, pp 6-1) Injectable form may cause low blood pressure

Possible side effects: Drowsiness, dizziness, blurred vision, rash

Figure 3 Inflight Compazine Checklist (35:6-3)

PHENERGAN - Anti-nausea, antihistamine

DO NOT USE WITHIN 6 HR OF TAKING SCOP/DEX.
DO NOT TAKE WITH COMPAZINE

Warning: Sedative effects may be additive with other central nervous system depressants. (See general warning about drug interactions, pp. 6-1) Spasms of head and neck muscles may occur with intramuscular injection

Possible side effects: Sedation, inability to concentrate, drowsiness, dizziness, blurred or double vision, nausea, rash

Figure 4 Inflight Phenergan Checklist (35:6-7)

SCOPALAMINE/DEXEDRINE - For motion sickness.

DO NOT USE WITHIN 6 HR OF TAKING PHENERGAN OR COMPAZINE. (See general warning about drug interactions, pp.6-1)

Warning:

Scopolamine - May cause drowsiness, inability to concentrate

Dexedrine - Do not use in a patient with high blood pressure; may impair the ability to concentrate

Possible side effects: Scopolamine - dry mouth, blurred vision, dilated pupils, dizziness.

Dexedrine - rapid heart rate, restlessness, dizziness, tremor, headache, loss of appetite

Figure 5 Inflight ScopDex Checklist (35:6-8)

A New Perspective

In 1986, AFIT motion sickness research discovered high amplitude low frequency brain wave activity (.1 to .2 Hz) during motion sickness (6). Based on the subdelta-delta brain wave observations, Dr. Chelen and Dr. Kabrisky hypothesized that motion sickness was a form of a psychomotor seizure and could be treated and prevented with an anticonvulsant drug (6). In 1987, AFIT conducted a "placebo controlled double blind crossover pilot study of acute motion sickness treatment/prevention in humans employing phenytoin" (6). Under the treatment, the two subjects tested had a 600 percent increase in tolerance to motion sickness (Figure 6) and suffered from none of the traditional side effects of blurred vision, dizziness, dry mouth or sedation (6).

Although, terrestial motion sickness is probably different from space motion sickness, the symptoms of both disorders are very similar. Therefore, a terrestial anti-motion sickness drug, such as phenytoin (dilantin), may also treat and prevent space motion sickness.

Additionally, if the sub-delta electroencephalogram (EEG) signals are significant parameters in the etiology, treatment and prevention of space motion sickness, then these EEG signals may also be significant in space motion sickness prediction models.

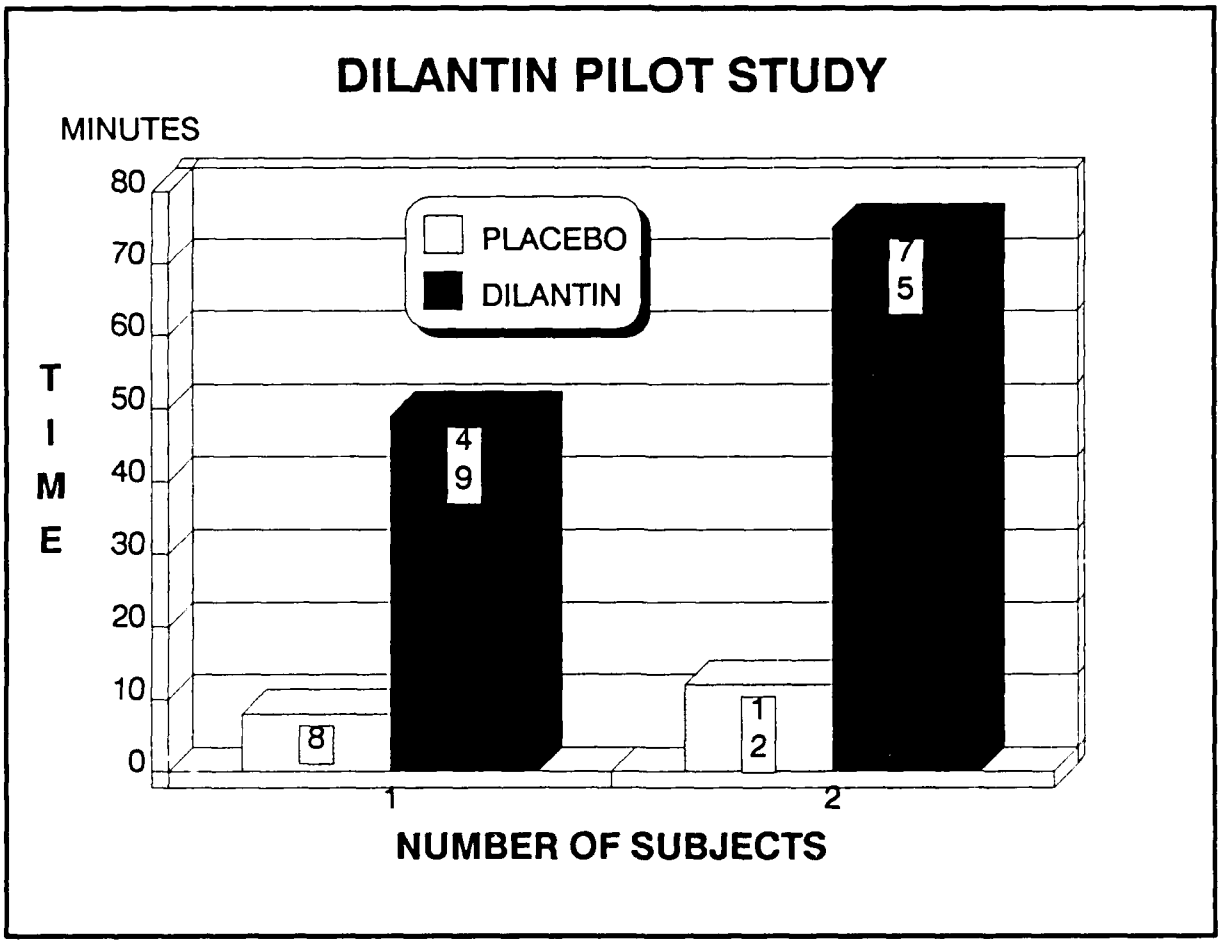

Figure 6 1987 Dilantin Pilot Study Results

Problem

The purpose of the study was to investigate the effect of the anticonvulsant agent, phenytoin (Dilantin), on laboratory induced motion sickness, and the use of neural network systems to process physiological data in order to predict space motion sickness preflight.

Scope

The research collected motion sickness data on seven male military subjects. The research did not include female subjects in the test because of safety considerations for subjects that might be pregnant.

Assumptions

1. Motion sickness induced in the laboratory is the same disorder as that produced by typical real world situations (5).

2. The physiological data - heart rate, brain activity, eye movement, gastro-intestinal activity, galvanic skin response, respiration, skin temperature and pallor - have a definite correlation to the degree of motion sickness in an individual (13;14;15;16;17).

3. Motion sickness is a form of a psychomotor seizure (6).

4. Motion sickness can be treated and prevented with an anticonvulsant drug.

5. The sub-delta EEG parameters can be used in a mathematical model and/or pattern recognition system to improve preflight SMS susceptibility prediction.

Methodology

The research was divided into four areas: Literature Review, Experimental Method, Experimental Results and Modeling.

Literature Review. The scope of the literature review was limited to recent (1961-1987) articles, theses, and reports related to space motion sickness, space adaptation syndrome, motion sickness, antimotion sickness drugs, antimotion psychological training, and neural networks. Sources were obtained from the Defense Technical Information center, other educational institutions, NASA, and Dr. William Chelen's published and non-published motion sickness papers. Personal interviews were also held with Dr. Chelen, NASA Johnson Space Center researchers, and NASA Ames Research Center researchers.

Experimental Method. This chapter includes detailed information on the subjects, the experimental procedures, and the materials, drugs, equipment and computer software used in the experiment.

Experimental Results. This chapter reports the observations and the results of the analyzed physiological data. The research analyzed the data using statistical analysis.

Modeling. This chapter describes and reports the results of: 1) a polynomial neural network used to model motion sickness and to predict motion sickness; and 2) a linear regression model used to predict motion sickness. This chapter also describes how either method could be used to predict space motion sickness preflight.

II. Literature Review

Scope

The scope of the literature review was limited to recent (1961-1987) articles, theses, and reports related to space motion sickness, space adaptation syndrome, motion sickness, antimotion sickness drugs, and antimotion sickness biofeedback training. These sources were obtained from the Defense Technical Information Center, other educational institutions, NASA and Dr. William Chelen's published and non-published papers. Personal interviews were also held with Dr. Chelen, NASA Jonson Space Center researchers and NASA Ames Research Center researchers.

Method Section

The literature review is divided into two major areas of motion sickness research. The literature review reports on the Air Force Institute of Technology's (AFIT) motion sickness research and the National Aeronautics and Space Administration's (NASA) space motion sickness research. Each of the major research areas is further subdivided into subsections. The AFIT research section is subdivided into a historical background subsection, a physiological response to motion sickness subsection, and an antimotion sickness drug subsection. The NASA section contains information from two NASA centers - Johnson Space Center and Ames Research Center - and contracted research centers. The NASA research section is subdivided into a historical subsection, a physiological response to motion sickness subsection, a prediction subsection, an antimotion sickness drug subsection, and an antimotion sickness psychological technique subsection.

AFIT Motion Sickness Research

Historical Background. AFIT researchers have been studying motion sickness for five years. In 1983, the Human System Division Commander, at Brooks AFB, Tesax, asked AFIT to investigate ground based motion sickness; specifically, to identify new biofeeback parameters and to develop an automated biofeedback treatment system (3). The first AFIT student research team, Earl and Peterson, assembled a rotating chair to induce motion sickness and developed a biophysical data acquisition system by combining commercial physiological monitoring equipment with physiological sensors that they had constructed (14).

In 1984, Fitzpatrick, Rogers and Williams attempted to automate the data collection process by developing the software and hardware necessary to integrate a MASSCOMP MC5500 computer into the system (11). In addition, they manufactured two new sensors for measuring gastrointestinal electric potential and eye motion (15).

In 1985, Jarvis and Uyeda continued studying motion sickness and were the first AFIT researchers to report any significant physiological experimental results (24). The researchers relied on strip chart recorders and magnetic tape for data collection because of difficulties with the MASSCOMP computer. They were joined by Dr. William Chelen, M.D., who redesigned and constructed new physiological sensors.

In 1986, Hartle, McPherson, and Miller moved the rotating chair and its support equipment to a location providing a better working environment. They eliminated the use of the MASSCOMP computer for data collection, preferring to rely on magnetic tape and strip chart recordings (32). Despite these time-consuming changes, they were able to experimentally identify several physiological trends

associated with the evolution of motion sickness (27:102-103; 24:87). They used statistical software to analyze their data and to develop equations predicting the levels of motion sickness experienced by a test subject during the course of an experiment (22:97).

In 1987, Drylie, Fix, and Gaudreault continued the collection of motion sickness data. They improved the system by standardizing test procedures and increasing the reliability of certain physiological sensors. The researchers also added a differential stethoscope for monitoring gastro-intestinal sounds, a bank of low pass filters to reduce incidental electrical noise, and a 16-channel strip chart recorder (16:7). They used a Zenith 248 computer and commercial signal processing software to digitize, display, and numerically analyze the experimental data. In 1987, Drylie and Gaudreault reported additional conclusions concerning motion sickness trends (13;17). At the same time, Fix developed a new equation for correlating physiological data with a volunteer's subjective sense of malaise (16:23). Fix also created a neural network simulation as another method of predicting a test subject's level of motion sickness (16).

Physiological Response to Motion Sickness. AFIT research teams have been studying and trying to understand the relationship of physiological responses to motion sickness. AFIT researchers have studied brain activity, heart rate, eye movement, gastro-intestinal activity, galvanic skin response, respiration, and skin temperature. Listed below are the findings of the physiological responses, mentioned above, to motion sickness.

Electroencephalograph (EEG). The EEG is used to observe the electrical activity of the brain (38:92). Brain waves recorded at the surface of the scalp vary in

intensity from about 5 to 1000 microvolts, and in frequency from about 0.05 Hz to 100 Hz (3). Five brain waveforms have been described in the literature - the DC potentials (0 - .05 Hz), delta wave (0.2 - 3.5 Hz), the theta wave (3.5 - 7.5 Hz, 50 - 200 microvolts), the alpha wave (7.5 - 13 Hz, 10 - 100 microvolts), and the beta wave (13 - 30 Hz) (26:92). In addition, the frequency range .05 - .2 hz is referred to as the subdelta frequency band (3).

The AFIT research teams have recorded EEG activity which appear to specifically accompany motion sickness. In 1986, Hartle, McPherson, and Miller reported "distinctive brain wave patterns" appearing with the onset of motion sickness, including an unexpected pattern in the 0.1 Hz frequency range (22:46). Drylie, Fix, and Gaudreault also noted low frequency EEG signals in the 0.1 Hz range (17:29). However, only one of their subjects had EEG signals with an amplitude change similar to that reported a year earlier (17:30).

Electrocardiograph (EKG). The EKG measures the electrical potentials generated by the heart (38:72). The AFIT research teams have used a Lead II configuration to monitor subject's hearts during motion sickness.

The AFIT studies have reported a few instances of sinus arrest (when a subject's heart rate drops to 30- 35 beats per minute) (22:70). Hartle, McPherson, and Miller observed three cases of sinus arrest during experimentation (22:70). The only case of sinus arrest reported in 1987, occurred when the subject was recuperating after the experiment (17:28). To prevent any possible danger to the test subject, AFIT researchers have always ended the experiment when sinus arrest appeared (4:12).

Electronystagmograph (ENG). The ENG measures the changes in potentials generated by movements of the eyeball (38:98). AFIT researchers have used one pair of ENG sensors to measure horizontal eye movements, and a second set to measure vertical eye motion (22:40).

AFIT researchers have been collecting ENG data for the past three years, and have not discerned any verifiable trend. In 1987, Drylie observed ENG signals increase in amplitude with the evolution of motion sickness (13:44). The 1986 team recorded ENG data on magnetic tape but did not analyze their results (22:51). In 1985, Jarvis and Uyeda furnished some spectral analyses of ENG data without comment (24:84).

Gastro-Intestinal Measurements. AFIT researchers have used different sensors for measuring gastro-intestinal activity. In 1985 and 1986, an electrogastrograph (EGG) and an electrointestinograph (EIG) were used. The EGG supposedly detected the electrical activity of the stomach, while the EIG presumably measured the activity of the small intestine (24:60-61). In 1987, a phonosplanchnogram was attached to the test subject's central abdominal region, and recorded bowel sound activity while an electrosplanchnogram made electrical measurements of the gastro-intestinal tract (16:13; 17:35).

Jarvis and Uyeda noted that abdominal electric potential increased with the evolution of motion sickness. They observed that the amplitude increases of EIG signals "ranged upwards of nearly fourteen-fold, with the maximum average increase approximately 400%" (24:95). The amplitudes of the EGG signals also increased during the experiments.

Hartle, McPherson, and Miller also found trends in gastro-intestinal activity during motion sickness. They noted that the abdominal electric potentials reflecting the activity of the small intestines "increased by about 400 percent" (22:80).

Finally, the 1987 team observed that the amplitude of the electrosplanchnogram signals "increased significantly" during motion sickness experimentation (13:41). Gaudreault found that the phonosplanchnograph recordings "revealed a decrease in peristalsis during the evolution of motion sickness for all subjects tested" (17:37). He concluded that the noise reduction "verifies that mechanical activity decreases as the frequency of the electrical activity increases in the gastro-intestinal tract" (17:37).

Galvanic Skin Response (GSR). GSR is defined as "the dynamic (decreasing) variation of skin resistance between two points on the skin in response to a stimulus" (38:57).

AFIT researchers have continually found that skin conductivity increases during the course of motion sickness (13:35; 22:68; 24:81). The trend has been ascribed to the increased sweating that accompanies the development of motion sickness (22:68; 24:81). However, the skin conductivity increase is primarily due to pseudomotor activity and capillary vascular activity (3). Other investigators have also noted the relationship between skin conductivity and motion sickness (44).

Pallor. A photoplethysmograph is used to "optically measure blood flow volume (skin pallor) changes at desired locations in the body" (24:57). In 1985 and 1986, the AFIT researchers used both facial and finger photoplethysmographs

(22:51; 24:57). Drylie, Fix, and Gaudreault used only a facial photoplethysmograph in 1987 (17:17).

AFIT test data agree with the generally accepted notion that skin pallor changes accompany the development of motion sickness (5; 21). Jarvis and Uyeda found that their experiments "essentially confirmed that pallor increases in the majority of subjects and generally precedes the onset of severe motion sickness" (24:87). Hartle, McPherson, and Miller also found that "pallor increases with the onset of motion sickness" (22:74). The 1987 team collected only two sets of photoplethysmograph data because of changes in the equipment and procedure (17:26). Nevertheless, Gaudreault was able to note that the data showed "both subjects becoming more pale, especially during severe malaise" (17:40).

Respiration. Respiration can be measured with two different instruments - pneumograph or spirograph. A pneumograph detects chest expansion and contraction (38:100). A spirometer measures lung volume by responding to air flow during inspiration and expiration (38:101).

AFIT researchers have measured changes in both thoracic and abdominal (diaphragmatic) respiration during motion sickness. However, equipment problems and motion artifact have hampered the collection and interpretation of the respiration data.

In 1985, Jarvis and Uyeda used "circumferential belts employing strain gauges" to measure respiration (24:60). They conducted spectral analyses of a few of their pneumograph recordings (24:84).

Hartle, McPherson, and Miller installed new pneumographs constructed by Dr Chelen (22:30). One pneumograph was used to measure abdominal respiration,

while the other detected thoracic respiration (22:41). In addition, they calibrated their respiration measurements by comparing them with breathing volume data obtained by having the test subjects exhale into a spirometer (22:74).

Both the 1986 and the 1987 research teams found a correlation between respiration and motion sickness. Hartle noted that, as the motion sickness symptoms developed, "the individuals had higher thoracic respiratory and diaphragmatic volume", indicating that the subjects were taking larger and less frequent breaths (22:79). In 1987, Drylie observed that while the frequency of breaths did not change during an experiment, the volume of each breath "increased significantly" (13:39). He interpreted these data as indicating that "a person begins to hyperventilate as he gets sick" (13:39).

Temperature. AFIT researchers have used thermistors to measure the peripheral skin temperature of their test subjects during motion sickness experiments.

The motion sickness research teams have differed in their interpretation of skin temperature data. In 1985, Jarvis and Uyeda observed that, as motion sickness evolved over time, temperature followed increasing linear, decreasing linear, or cyclical trends (24:90). A year later, Miller decided that "temperature does not provide a really strong basis for incorporating it into the family of real good predictors of motion sickness" (29:65). Hartle felt that the temperature readings could have been adversely affected by the room environment (22:72).

In 1987, Drylie reported that "subject temperature did not change significantly" during the course of an experiment (13:37). However, Fix used temperature changes in his equation for predicting subjective levels of motion sickness (16:16).

Anti-Motion Sickness Drugs. AFIT researchers have tested, in a pilot study, an anticonvulsant drug, phenytoin (dilantin), on motion sickness (5). Phenytoin is primarily used to control certain seizures of epilepsy (3;5;6). According to Chelen, "a greater than six times increase in the tolerance to motion sickness was obtained" (6). Chelen also pointed out, "there were none of the traditional side effects of blurred vision, dizziness, dry mouth, or sedation" (6).

Two important discoveries led to the the testing of phenytoin on motion sickness. In 1987, Drylie, Fix and Gaudreault observed low frequency EEG signals in the 0.1 Hz range (5). Such low frequency brain signals usually occur during or after a psychomotor seizure. The second revelation was that motion sickness symptoms, such as epigastric sensation, gastrointestinal hypermotility, cardiovascular, respiratory, and other autonomic dysfunctions, were virtually identical to psychomotor seizure (5).

NASA Research

Historical Background. During the first two U.S. space programs, Mercury and Gemini, there were no reports of space motion sickness (23:36-1). The first U.S. episode of space motion sickness occurred during the Apollo program. Approximately 35 percent of the Apollo crew members reported space motion sickness symptoms (23:36-2). The incidence of space motion sickness increased to almost 60 percent during the Skylab missions (23:36-2). In 1984, Homick, Reschke, Vanderploeg attributed the increase of space motion sickness, during the Apollo and Skylab missions, to an "increased incidence of vestibular and other sensory rearrangement problems" (23:36-2). The heightened activity in both the vestibular

and other sensory systems was due to the increased mobility the crews had within the larger spacecraft (23:36-2). The increased interior volume of the spacecrafts, Apollo and Skylab, allowed the crewmembers to move about more freely; thus, the increased mobility heightened vestibular and other sensory inputs.

Because of the high incidence of motion sickness during the Skylab mission NASA researchers and astronauts were aware of the possibility that motion sickness could occur on future Space Shuttle missions. Unfortunately, with the loss of Skylab, NASA researchers were unable to continue studying SMS and to develop an adequate treatment. As a result, the incidence of sickness during the first nine Shuttle flights exceeded 50 percent (23:36-2). Consequently, "in an effort to resolve the SMS, or at least minimize the operational impact of the syndrome, NASA has significantly expanded its research and development efforts in this area" (23:36-1). According to Reschke, Homick, Ryan, Mosely, NASA researchers "mounted a considerable effort to treat, predict, and explain" space motion sickness (40:26-1).

Physiological Response to Motion Ssickness. NASA Ames researchers support the assumption that there are "profound autonomic nervous system (ANS) changes associated with" motion sickness (9:542). In 1986, Cowings, and others reported "The relative importance of ANS responses in understanding and treating motion sickness has been a matter of some controversy" (9:542). Early ANS studies in the 1970s de-emphasized the importance of ANS in motion sickness (9:542). According to the research conducted by Money in 1970, and discussed by Cowings, Suter, Toscano, Kamiya, Naifeh, "... to the extent that motion sickness is nausea and vomiting, it is not an autonomic phenomenon and cannot be considered a development of the autonomic effects of vestibular stimulation" (9:543). According to Graybiel and Lackner in 1980, and discussed by Cowings, Suter, Toscano,

Kamiya, Naifeh, "Such measures, therefore, appear to have little value in assessing or diagnosing severity of motion sickness" (9:543).

In contradiction to the Money study and the Graybiel and Lackner study, the NASA Ames researchers have observed significant changes in autonomic responses during motion sickness (9:549). NASA Ames researchers have studied heart rate, respiration rate, finger pulse volume, and basal skin resistance. Listed below are the findings of the physiological responses, as mentioned above, to motion sickness.

Electrocardiograph (ECG). NASA-Ames researchers have reported:

> Heart rate responded vigorously to motion sickness stimulation. The overall magnitude of HR response was related to motion sickness susceptibility, with those who were more susceptible showing greater changes in HR, even within the first 2 min. When rotation stopped HR returned quickly to pretest levels. (9:548)

Basal Skin Resistance. NASA-Ames researchers have reported:

> BSR decreased during motion sickness stimulation, and then recovered afterward. Those who were highly susceptible to motion sickness experienced a decrease in BSR as they became sick. Basal skin resistance did not recover to pretest levels within 5 min after the termination of rotation. (9:548)

Pulse Volume. NASA-AMES researchers have reported:

> Following an abrupt drop in PV at the onset of rotation, PV gradually increased as motion sickness stimulation continued. The most susceptible participants experienced decreased PV as motion sickness developed. There was a rebound increase in PV when rotation stopped, followed shortly by a decrease. (9:548)

Respiration. NASA AMES researchers have reported:

> RR increased with the onset of rotation, recovered as rotation continued, and then increased across the several minutes leading to termination. Respiration rate decreased to pretest levels in the 5 min following the end of rotation. (9:548)

Prediction. Early in the Shuttle program, the Neurophysiology Laboratory at the Johnson Space Center was tasked to develop techniques to predict space motion sickness for the purpose of "applying possible countermeasures" (40:26-1). Previous means of predicting space motion sickness have not been very reliable (40:26-1). Reschke, Homick, Ryan, Mosely suggested that the difficulty in predicting space motion sickness was a result of studies frequently hampered "by limited access to the astronaut population and the small number of crew involved in spaceflight" (40:26-1).

The objectives of the Reschke, Homick, Ryan, Mosely study were: 1) To describe the univariate and multivariate relationships of the current battery of provocative and non-provocative measures; 2) To develop and cross-validate sets of linear equations that optimally predict motion sickness using predetermined sets of tests; and 3) To determine the inherent properties of the various tests in a multivariate setting (40:26-1).

The Reschke, Homick, Ryan, Mosely study consisted of eight tests for motion sickness. These tests included:

1) the Coriolis Sickness Sensitivity Index (CSSI)

2) an off-vertical rotation test

3) a sudden-stop test with an optokinetic stimulus

4) a sudden-stop test without an optokinetic stimulus

5) a staircase velocity test similar to the CSSI

6) motion sickness susceptibility during parabolic flight

7) tests of Vestibular Ocular Reflex phase and gain

8) Postural ataxia measurement

(40:26-1)

Reschke, Homick, Ryan, Mosely used factor analysis results to predict motion sickness symptoms on the KC-135 flights 73 percent of the time; however, the "equations developed on the normative group for sex, age, and Coriolis Sickness Sensitivity Index were not effective in predicting crewman's space adaptation to the first nine Shuttle flights" (28:26-11).

During the Spacelab 1 mission a space motion sickness monitoring experiment was performed (39:35-1). Oman, Litchtenberg and Money tested four crew members for motion sickness susceptibility preflight. The tests included both ground based and airborne experiments (39:35-1). One objective of the mission was to compare the susceptibility of preflight tests with the "susceptibility to the stimulus of spaceflight" (33:33-1). The researchers hoped to gain further information on space motion sickness and, possibly, "a technique for predicting susceptibility to space sickness or a technique for effective prehabituation" (33:33-1).

The space motion sickness experiment results indicated that the subject considered the most susceptible to space sickness, based on preflight tests, turned out to be the least susceptible to the malady and the subject considered least susceptible to space sickness turned out to be the most susceptible to space sickness (33:33-6). Furthermore, the left-right reversing prisms test results were very similar to the actual Spacelab experiment results. In the reversing prisms test "subject D was judged to be least susceptible to the sickness and most adaptable to the new

environment" (33:33-6). Based on the reversing prisms test results and the space motion sickness experiment results, Oman, Lichtenberg and Money suggested "Possibly, people who find that a change in the gain of the vestibular-ocular reflex is provocative, and who adapt slowly to such a change, are people who are susceptible to space motion sickness" (33:33-6).

Anti-motion Sickness Drugs. NASA researchers have relied on antimotion sickness drugs to counter the effects of space motion sickness (23:36-1). NASA researchers have also admitted that "drugs are an imperfect solution because their side effects can impair performance" (26:36).

During the first nine Space Shuttle missions "The use of oral antimotion sickness drugs to treat and prevent space motion sickness has not been especially effective" (20:1;23:36-1). As mentioned earlier, approximately 50 percent of the crew members of the first nine Space Shuttle missions reported space motion symptoms (23:36-1). According to Homick, Reschke, Vanderploeg, "Anti-motion sickness and/or anti-emetic medication was used by 21 of the 29 individuals who flew during the first nine Space Shuttle missions" (23:36-4).

Generally, oral scopolamine (0.4mg) plus dexedrine (5.0mg) is the preferred medication used to treat space sickness (18:36-2). The dexedrine is taken to counteract the depressant effects of scopolamine. Specifically, scopolamine is an anticholinergic (depressant) drug whereas dexedrine (stimulant), known as dextroamphetamine, is a potent amphetamine (27:82,146). According to Julian:

> Low doses of scopolamine depress the arousal centers in the ascending reticular activating system (ARAS) of the brain, induce a cortical brain-wave pattern characteristic of sleep, and produce drowsiness, euphoria, amnesia, fatigue, delirium, mental confusion, dreamless sleep, and loss of attention. (27:147)

On the other hand, moderate doses (5 to 50 mg) of dexedrine produces stimulation of respiration, slight tremors, restlessness, increased motor activity, insomnia and agitation (27:82).

On occasions astronauts have also orally taken, in combination, promethazine (25mg) plus ephedrine (25 mg) to treat space motion sickness symptoms (23:36-2). Promethazine belongs to a class of medicines called phenothiazine derivative (43:394). Promethazine produces dry mouth, dilated pupils, blurred vision and drowsiness (43:3942). Ephedrine is structurally related to amphetamine, but its effect on the central nervous system is much milder than amphetamine (27:88). Consequently, the ephedrine is used to counteract the drowsiness effect of the promethazine.

There have been crew reports of some temporary relief from motion sickness when treated with oral antimotion drugs but in most cases these therapeutic agents have had little effect in treating space motion sickness. Graybiel and Lackner pointed out that antimotion sickness drugs tend to have less effect in treating symptoms if the malady already exists (19:773). They have attributed this phenomenon to: 1) the inability of a drug taken by mouth to be normally absorbed by the body due to the decreased gastric motility caused by motion sickness; and 2) the transportation of drugs through the bloodstream may be altered by the "microgravity environment" (19:773). To overcome this phenomenon, Graybiel and Lackner conducted experiments to study the effects of antimotion sickness drug injections on motion sickness (15:773). Their results suggests that "antimotion sickness drug injections may provide temporary relief for individuals who are" suffering from severe space motion sickness (19:776).

Anti-motion Sickness Psychophysiological Techniques. Another approach in the treatment of space motion sickness has been the psychophysiology approach (26:36). The objective of this approach is to be able to alter psychophysiologic functions. and includes such techniques as biofeedback, autogenic therapy, hypnosis, desensitization therapy, and meditation. A common and key attribute in the psychophysiological approach is relaxation. NASA researchers have concentrated on autogenic therapy and biofeedback as treatments in space motion sickness(26:36).

For the past 15 years, NASA Ames researchers have been conducting motion sickness experiments. Most of the research at NASA Ames has been focused on Autogenic-Feedback Training (AFT) (9:542). AFT is a combination of biofeedback and autogenic training "which involves training in physiological self-regulation as an alternative to pharmacological management" (9:542). The basis for AFT is that there are profound autonomic nervous system changes associated with motion sickness (as reported by the AFIT and NASA Ames research teams). NASA researchers have been able to train subjects to control such physiological functions as "heart rate, skin conductance, depth and rate of respiration, and the flow of blood to the hands" (26:36). Recently, four astronuats participated as subjects in an autogenic-feedback experiment during the Spacelab 3 mission (8:34). Two crewmen were treated using AFT and two other crewmen were control subjects (8:34). According to Cowings "When the inflight physiological data of crewmen A was compared to that of other crewmen participating in this study, he showed reduced sympathetic tone for all physiological variables measured" (8:36).

Nonpharmological approaches in treating motion sickness (e.g. autogenic and biofeedback techniques) have had promising results, but according to Homick, Reschke, Vanderploeg, these approaches "have not matured to the stage where they can be applied in a routine fashion for astronauts" (23:36-6).

III. METHOD

This chapter includes detailed information on the subjects, the apparatus, the experimental procedure, and the data analysis procedure.

Subjects

Seven males, between the ages of 21 and 35, served as subjects in this research. All of the subjects were members of the United States Air Force. Six of the males were Caucasian; one was Oriental. The research used the Air Force Institute of Technology Bulletin, flyers and word of mouth to recruit subjects. Subjects were allowed to keep their "AFIT Made Me Sick" t-shirt as the sole reward for their services. All of the subjects completed the entire experiment.

Apparatus

Stimulation Device and Recording Equipment. A powered rotating chair was used to provoke motion sickness symptoms in subjects. The combination of the chair rotating in the yaw axis and the subjects in the chair executing voluntary head movements left, right, down and up produced sufficient coriolis stimulation to induce symptoms of motion sickness.

A Radio Shack wireless intercom device was used to monitor the subject's comments during the experiment. The intercom device was attached to the upper rear of the chair. Additionally, a Marshall Electronic Astropulse 90 sphygmomanometer and physiological amplifiers were mounted to the side of the chair and the physiological signals from these devices were routed through the chair's slip rings to a sixteen channel low pass filter bank located at the data

recording station. The low pass filter removed 60 hertz noise from the data channels and distributed the signals simultaneously to a Soltec model 8k20 sixteen channel strip chart recorder and a Kyowa Dengyo fourteen channel beta tape instrumentation recorder. The Kyowa recorder also routed eight physiological signals to a Zenith Z-248 computer. These signals were digitized and displayed in real time on the Z-248 using DATA Instrument's eight channel analog-to-digital converter, waveform scroller and CODAS software package.

Physiological Monitoring Devices. The research monitored sixteen physiological responses to motion sickness. The research used special amplifiers, designed and built by Dr. Chelen, as physiological sensors. These amplifiers were fully described by Gaudreault (17:21-24). Table 2 provides a list of the monitoring devices, their placement and how they were recorded. Figure 7 shows the placement of silver/silver chloride electrodes, strain gauges, photoplethysmograph transducers and a DIF-STET differential stethoscope on the chest and hand. Figure 7 shows the placement of silver/silver chloride electrodes, photoplethysmograph transducers on the face, and Figure 8 shows the placement of platinum subdermal electrodes on the scalp.

Electrocardiograph. EKG data were collected using ambulatory silver/silver chloride electrodes. A lead II configuration was used on all the subjects.

Pneumographs. Respiration data were collected using two strain gauge belts. One belt was placed around the chest to detect thoracic respiration data and the other belt was placed around the abdomen to detect diaphragmatic respiration data.

Electroencephalographs. Electroencephalograph (EEG) data were collected using ten platinum subdermal electrodes. To eliminate sweat artifact, subdermal electrodes were used instead of surface electrodes. To reduce the subjects' discomfort, a skin refrigerant was applied to the scalp before the electrodes were inserted. A bipolar channel configuration was used on the subjects consisting of a Fz-Cz channel, a Pz-Oz channel, a C4-T4 channel, a T3-C3 channel, and a F3-F4 channel (see Figure 9).

Electrosplanchnographs. The electrosplanchnographs measured gastrointestinal electrical activity. A pair of surface ambulatory silver/silver chloride electrodes were placed over the upper left quadrant of the abdomen and on the right lower quadrant of the abdomen to collect skin surface electrical potentials from the stomach and the intestines.

Photoplethysmographs. Skin pallor data were derived from two facial photoplethysmograph transducers and one finger photoplethysmograph transducer. The finger photoplethysmograph also detected blood pulse volume.

Electronystagmographs. Two sets of miniature silver/silver chloride electrodes were used to measure eye movements. One set of electrodes were placed above and below one eye to measure vertical eye movements and the other set was placed on the right and left temple to measure horizontal eye movement.

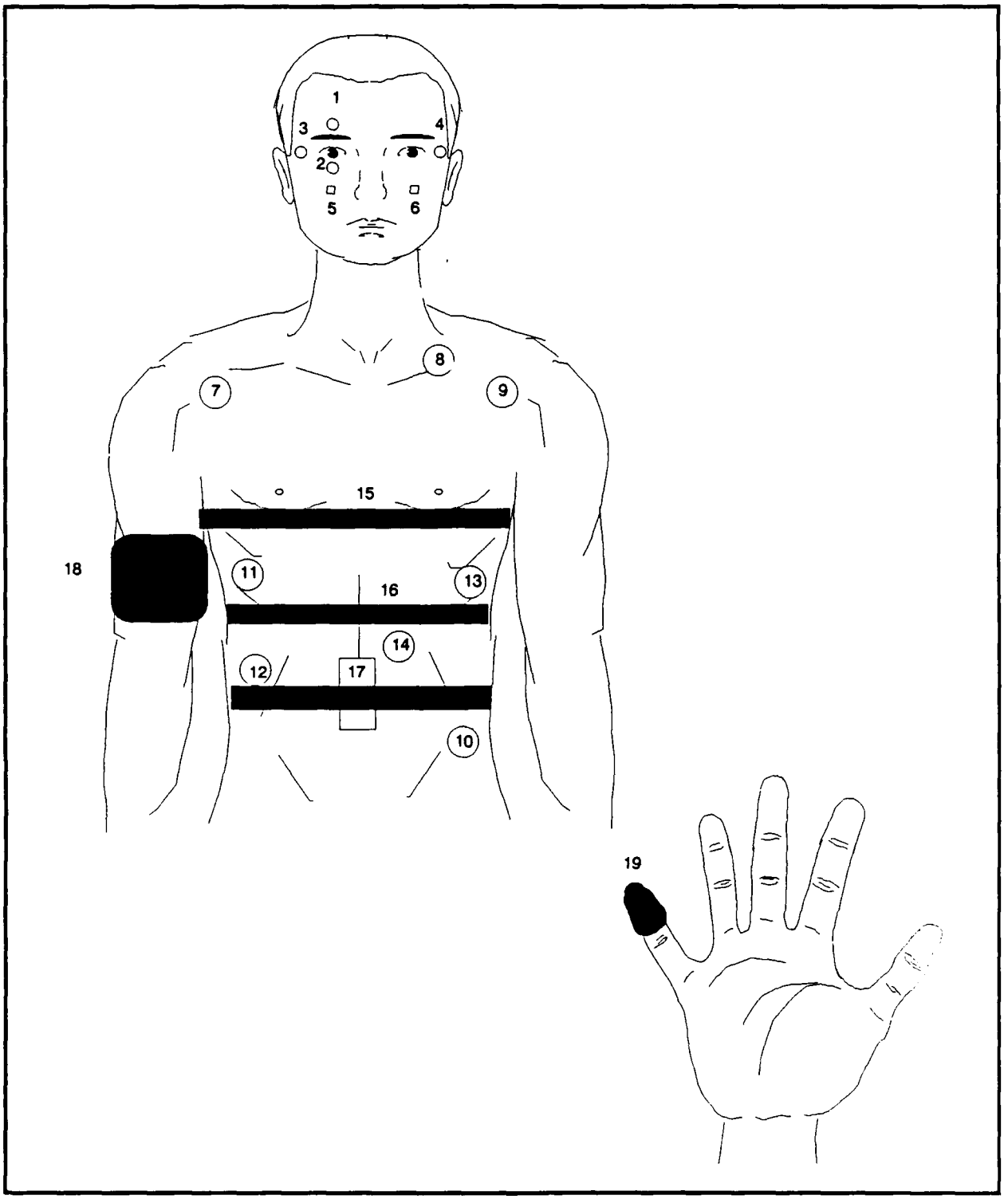

Figure 7 Body Sensor Placement

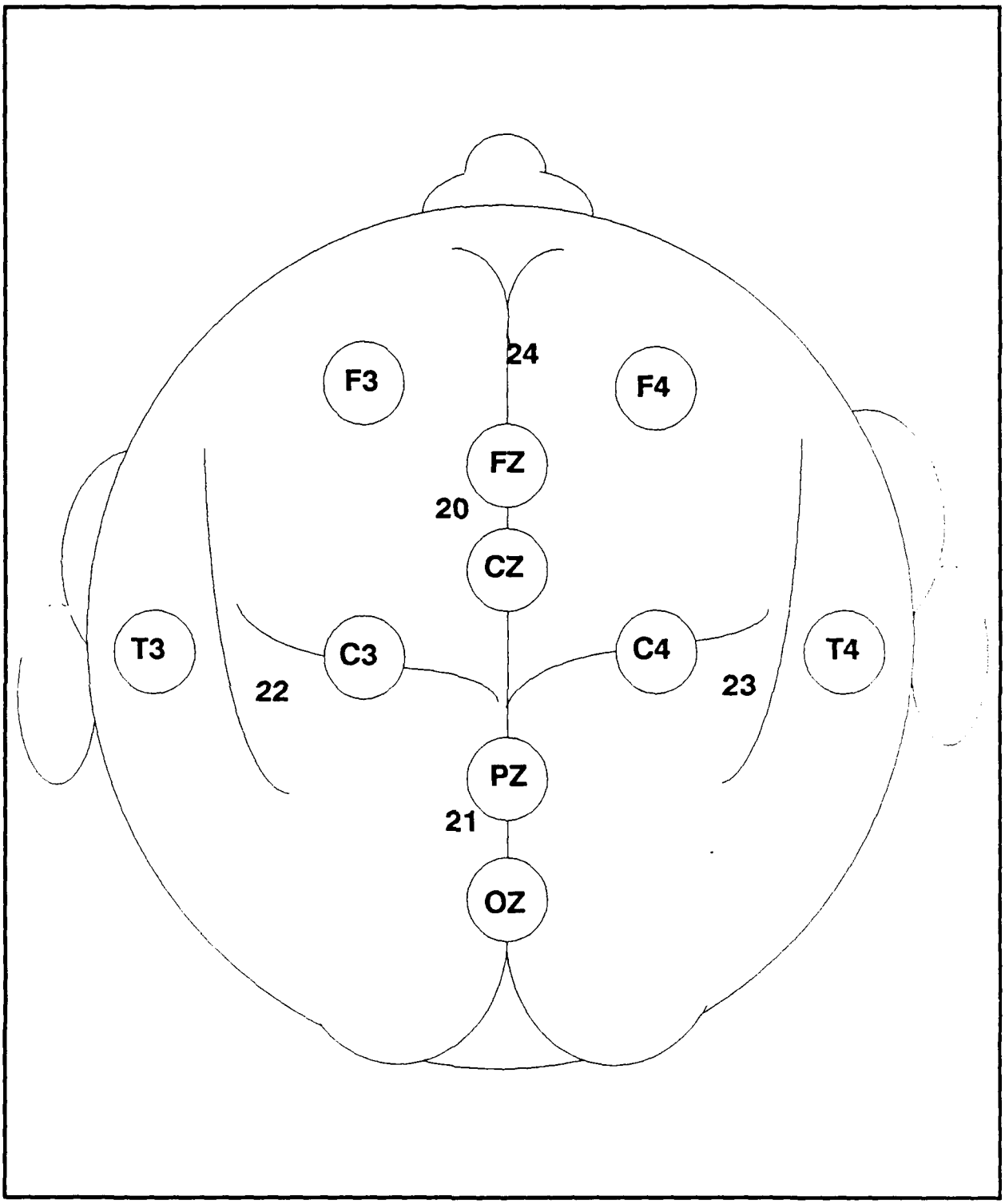

Figure 8 EEG Sensor Placement

Table 2 Monitoring Devices, Placement and Recording List

PLACEMENT NUMBER	MONITORING DEVICE	BETA CHANNEL	STRIP CHART CHANNEL
1	ENG VERTICAL +	6	6
2	ENG VERTICAL -		
3	ENG HORIZONTAL +	5	5
4	ENG HORIZONTAL -		
5	FACIAL PHOTOPLETHYSMOGRAPHS	7	7
6	FACIAL PHOTOPLETHYSMOGRAPHS	-	8
7	EKG +	1	1
8	EKG GROUND	-	-
9	EKG GROUND	-	-
10	EKG -	1	1
11	ESG RLQ +	-	13
12	ESG RLQ -		
13	ESG LUQ +	10	12
14	ESG LUQ -		
15	PNEUMOGRAPH (THORACIC)	9	10
16	PNEUMOGRAPH (DIAPHRAGMATIC)	-	9
17	PHONOSPLANCHNOGRAPH	14	-
18	SPHYGMOMANOMETER	-	-
19	FINGER PHOTOPLETHYSMOGRAPH	11	14
20	EEG 1A (FZ-CZ)	2	2
21	EEG 1B (PZ-OZ)	3	3
22	EEG 1C (C3-T3)	4	4
23	EEG 2A (C4-T4)	12	15
24	EEG 2B (F3-F4)	13	16

Ballistocardiograph. The thoracic strain gauge belt was used to measure chest rebound from the heart beating.

Phonosplanchnograph. An INTECH Systems' DIF-STET differential stethoscope was used to measure gastrointestinal sounds. This device was placed periumbilically on the abdomen.

Data Analysis Equipment and Software. Data were analyzed offline using both the strip chart recorder and the beta recorder/Z-248/DATQ Instrument hardware and software configuration. Data were also analyzed on the Z-248 using MacMillan's Asystant scientific software package and Borland's Quattro spreadsheet software package.

Procedure

The research used a double blind, placebo controlled crossover technique to investigate the efficacy of phenytoin (dilantin) during ground based motion sickness. The procedure used in the experiment consisted of a pre-trial phase and a trial phase.

Pre-trial Phase. During this phase, the research screened subjects in order to eliminate those with abnormal vestibular systems, allergies to medication, or an abnormal state of health. Baseline data were also collected on the subjects during this phase. The pre-trial phase included a medical history and motion sickness interview, a balance test, a motion susceptibility trial, a physical examination, blood tests, and a performance-cognitive test.

Medical History and Motion Sickness History. Subjects filled out a medical history form and a motion sickness questionnaire. The research used the medical

history form to collect both personal and family medical history on the subjects. Subjects with familial or genetic disorders or chronic and systemic disease were excluded from the research. The research used a motion sickness questionnaire to collect information on how susceptible subjects were to motion sickness and what types of motion were most provocative to them. The information from this questionnaire was also used to determine the speed of the powered rotating chair during the susceptibility trial.

Balance Test. The research had subjects perform a balance test in order to determine if the subjects had a normal vestibular system. The test had subjects lift one leg and then close their eyes. This procedure eliminated subjects' visual input and forced their proprioceptive and vestibular system to maintain balance (3). Subjects with a deficient vestibular system would lose their balance and fall over. These subjects were eliminated from the research because they would not be susceptible to coriolis induced stimulation.

Motion Susceptibility Trial. The objective of this test was to determine the subject's susceptibility to ground based induced motion sickness. The susceptibility trial consisted of a ride in the powered rotating chair at 14 to 22 revolutions per minute for several minutes. Noninstrumented subjects were placed in the powered rotating chair and blindfolded. During rotation an audio tape player directed the subjects to perform head movements right, left, down and up. The subjects were periodically asked to report their symptoms and to rate their symptom level on a scale of 1 (normal) to 10 (imminent emesis).

Physical Examination. Dr. Chelen performed a complete physical examination on each subject. After the examination, subjects underwent a complete blood count (CBC), a general battery of blood biochemistry, blood lipids and cholesterol count, urinalysis and liver function studies.

Performance-Cognitive Test. After the physical examination, subjects had their physical performance and cognitive skills tested. To evaluate side effects of dilantin, these baseline tests were later compared to performance-cognitive tests given to subjects after treatment (placebo and dilantin). These tests were developed by the Air Force Aerospace Medical Research Laboratory and operated on a personal computer. They consisted of a probability monitoring task to test visual perceptual input, a grammatical reasoning task to measure reasoning ability and an unstable tracking task to test manual response speed and accuracy (42).

Trial Phase. The day before the trial, subjects were given two envelopes (envelope A and envelope B); one contained a dextrose placebo and the other contained dilantin. The number of capsules in the envelopes varied depending on the weights of the subjects. A therapeutic phenytoin (dilantin) blood level of 10 to 20 micrograms per milliliter was the goal for each subject. The subjects shuffled the envelopes and chose one at random. The subjects also did not reveal their selection until after the second experiment. The subjects took a test dose the afternoon before the trial to allow Dr. Chelen to monitor their reaction to the treatment. If the subjects had a reaction to the treatment they were not allowed to continue with the experiment; otherwise, they began a treatment schedule of one with dinner, one

with a snack before going to bed, one (possibly two) with breakfast and one (possibly two) with lunch.

The day of the trial, about an hour before the experiment, the subjects' performance-cognitive skills were tested again. After the performance-cognitive test, Dr. Chelen asked the subjects to report any unusual reactions to the treatment.

The physiological monitoring devices, previously mentioned in the apparatus section, were then attached to the subjects and calibrated. Pallor was calibrated by removing blood from the subjects' hand using a wraping technique with an elastic wrap and a sphygmomanometer. Once the blood was forced out, the photoplethysmogram transducers were then attached to the left hand and calibrated at the maximum possible pallor. The pressure from the sphygmomanometer was released, enabling the sensors to be calibrated for maximum flush. The remaining physiological monitoring devices were placed on the subjects after their abdomens, trunks and heads were cleaned with alcohol pads. At this point, blood was drawn from the subjects in order to quantitatively determine the dilantin blood serum levels. The subjects were then placed in the powered rotating chair. A microphone was taped to the side of their mouths, their respiration was calibrated using a spirometer. Finally, electronystagram sensors were tested after the subects had been blindfolded.

Following a resting baseline of five minutes (C1 - C5), rotation was started and increased immediately to the subjects' maximum rotation speed (which was based on their susceptibility trial). As in the susceptibility trial, the audio tape player directed head movements. The subjects were constantly monitored and were periodically

asked to report their symptoms and to rate their symptom level on a scale of 1 (normal) to 10 (imminent emesis). The experiment continued until emesis.

When the subjects reached emesis the chair was decelerated very slowly. After the chair stopped, the subjects remained seated in order to collect ten minutes of post emesis (PE1 - PE10) data and to allow them to recover. At the end of ten minutes the experiment was terminated.

Data Analysis

This research analyzed electrocardiogram (EKG) data, thoracic pneumogram (RESP) data, electrosplanchnogram (ESG) data and electroencephalogram (EEG) data. This research also used the Miller and Grabiel diagnostic scale to quantify subjects' malaise levels during motion sickness (31). Both the subjects' symptom reports and AFIT's symptom levels 1 (normal) to 10 (imminent emesis) were used to identify the malaise levels (see appendix B). Data were collected and analyzed for both the placebo and treatment trials. To ensure that accurate motion sickness mathematical models were develop, continuous placebo trial data were analyzed. Continuous data for EKG, RESP, ESG and EEG parameters were analyzed for an entire five minute control period (C1 - C5), an entire asymptomatic period, an entire slight malaise period (MI), an entire moderate malaise B period (MIIB), an entire moderate malaise A period (MIIA), an entire severe malaise period (MIII), an entire frank sickness period (FS) and an entire five minute post emesis period (PE1 - PE5). EKG, RESP, ESG and EEG data collected during the treatment trials were also analyzed but only thirty seconds of data were collected during the control

periods and post emesis periods and no more than one minute segments of data were collected during the other periods.

Electrocardiogram. EKG data were digitized at 100 samples per second using the CODAS software. Inter-beat-intervals (IBI) of the heart were obtained by measuring R to R wave intervals. Instantaneous heart rates (IHR), in beats per minute (BPM), were then calculated using the following equation:

$$IHR\ (BPM) = (1/IBI) * 60 \qquad (1)$$

where

IHR = instantaneous heart rate (beats per minute)

IBI = inter-beat-interval (msec)

Pneumogram (Thoracic). Thoracic respiration data were digitized at 10 samples per second using the CODAS software. Respiration volume data were obtained by measuring the strip chart recording thoracic peaks.

Electrosplanchnogram. Right upper quarter ESG data were digitized at 5 samples per second using the CODAS software. RMS voltages were calculated using the Asystant software.

Electroencephalogram. To analyze the subdelta-delta (.05-1 Hz) EEG data a low pass filter was constructed by Dr. Chelen. This low pass filter corrected the 3 dB per octave rolloff between .05 - 1Hz band that is built into the EEG amplifiers. EEG data were digitized at 10 samples per second using the CODAS software. Using channel 1A (Fz-Cz) data, root mean square voltages (VRMS) and peak voltages were calculated using the Asystant software.

IV. Results

Physiology Parameters

Hypothesis testing techniques (paired t test) were used to statistically analyze the means of the physiological parameters of the placebo trials versus the physiological parameters of the phenytoin (dilantin) trail.

Heart Rate (Beats per minute).

Placebo Treatment. The mean heart rates per period (see Table 3) are depicted in Figure 9. These heart rates increased (in a stair step fashion) with the increase of motion sickness. Specifically, mean heart rates increased during the asymptomatic, MI, MIIA and frank sickness periods, while decreasing slightly during MIIB and MIII periods. The decrease in heart rates suggest that subjects were adapting to the motion stimulus. The maximum mean heart rate at frank sickness was 26% greater than the minimum mean heart rate at control period 2. The mean heart rates took about five minutes to recover to baseline levels.

Dilantin Treament. The mean heart rates per period (see Table 4) are also depicted in Figure 9. In general, these heart rates decreased with the evolution of motion sickness. The major increase in mean heart rates occured during the asymptomatic period and may be due to the subjects' high anxiety levels. Mean heart rates slightly increased during frank sickness but dropped to baseline levels within one minute after emesis. Five minutes after emesis, the mean heart rates dropped an additional 7%.

Table 3 Mean Heart Rates of Subjects Treated with Placeb

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	-	74	-	70	54	65	61	64.8
CONTROL 2	-	67	-	68	60	66	58	63.8
CONTROL 3	-	71	-	74	58	65	60	65.0
CONTROL 4	-	69	-	66	67	68	71	65.4
CONTROL 5	73	77	-	72	76	67	73	70.8
ASYMPTOMATIC	75	95	-	72	85	68	77	77.6
MI	78	85	74	73	77	83	-	79.0
MIIB	81	78	71	71	82	80	-	77.1
MIIA	76	83	-	-	82	86	-	81.7
MIII	80	94	69	-	77	84	-	80.8
FRANK SICKNESS	80	81	94	84	88	90	-	86.1
POST EMESIS +1	84	82	85	70	67	80	-	78.0
POST EMESIS +2	86	-	81	67	68	70	-	74.4
POST EMESIS +3	-	-	78	68	66	66	-	69.5
POST EMESIS +4	-	-	70	-	66	65	-	67.0
POST EMESIS +5	-	-	73	-	60	63	-	65.3
MEAN PERIODS A-FS	78.3	86	77	75	81.8	81.8	73.6	

Placebo vs. Dilantin. The data suggest that the mean heart rate of subjects (periods A-FS) treated with dilantin are lower than the mean heart rate of subjects (periods A-FS) treated with the placebo (alpha = .01, test statistic t = 2.9565, DF = 6 and $P(Z < t) = .0158$)

Table 4 Mean Heart Rates of Subjects Treated with Dilantin

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	-	67	76	66	70	61	73	68.8
CONTROL 2	-	70	66	67	65	55	-	64.6
CONTROL 3	-	72	72	69	56	55	-	64.8
CONTROL 4	-	72	76	67	64	58	-	67.4
CONTROL 5	-	70	77	80	64	56	-	69.4
ASYMPTOMATIC	-	100	72	72	69	58	78	74.8
MI	-	77	68	62	65	-	79	70.2
MIIB	-	87	73	59	66	-	68	70.6
MIIA	-	74	-	-	66	-	72	70.6
MIII	-	82	-	-	68	-	58	69.3
FRANK SICKNESS	-	83	-	-	61	-	71	71.6
POST EMESIS +1	-	-	-	-	55	-	75	65.0
POST EMESIS +2	-	-	-	-	56	-	74	65.0
POST EMESIS +3	-	-	-	-	60	-	73	66.5
POST EMESIS +4	-	-	-	-	57	-	70	63.5
POST EMESIS +5	-	-	-	-	57	-	64	60.5
MEAN PERIODS A-FS	-	83.8	71.0	64.3	58.0	65.8	71.0	

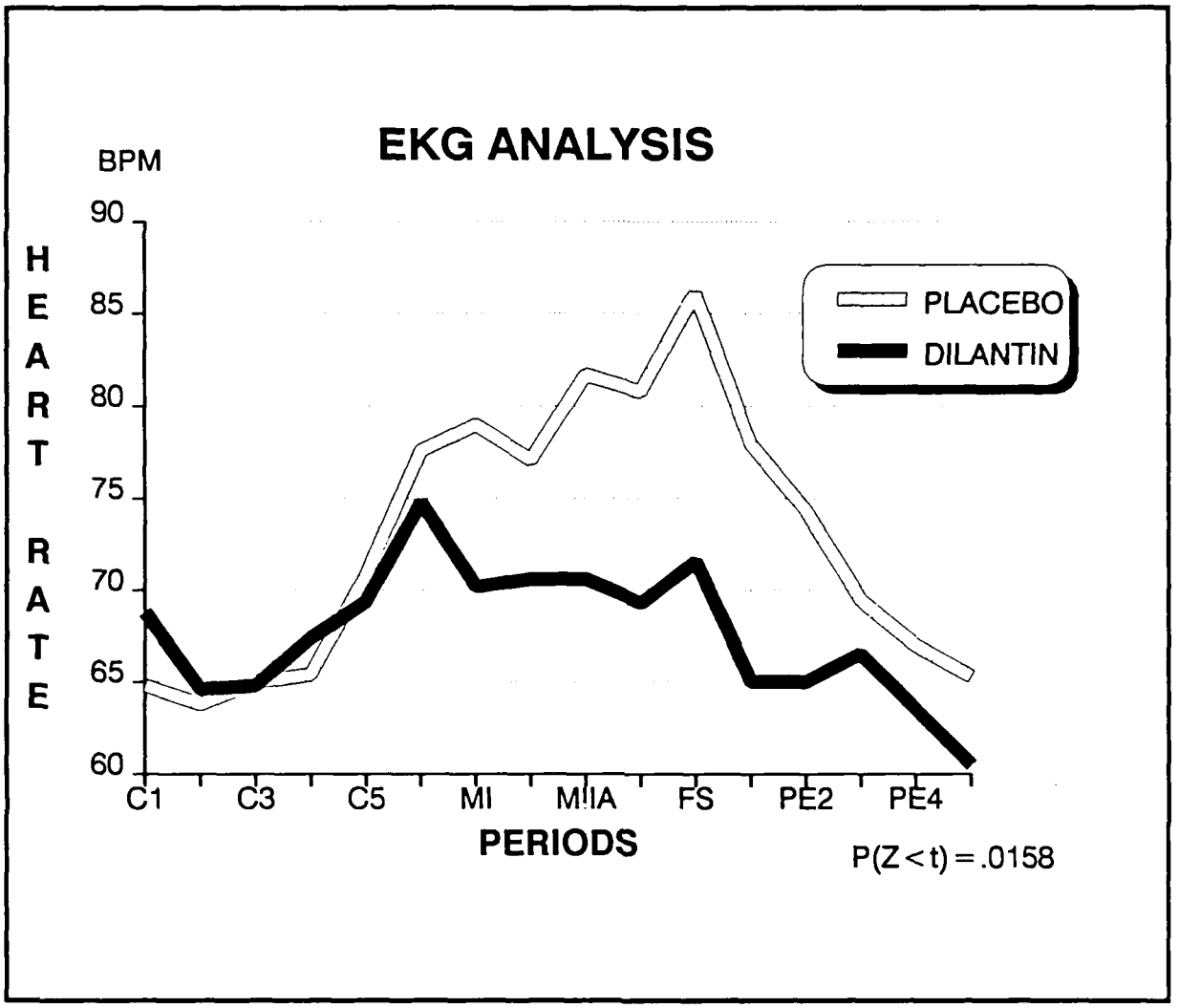

Figure 9 Mean Heart Rates of Subjects Treated with the Placebo and Dilantin

Respiration Volume (Volume per Period).

Placebo Treatment. The mean respiration volumes of subjects per period (see Table 5) are depicted in Figure 10. These respiration volumes increased (in a stair step fashion) with the increase of motion sickness. The maximum mean respiration volume at frank sickness was 67.9 % greater than the minimum mean

respiration volume at control period 1. Five minutes after emesis, the mean respiration volumes did not return to baseline levels.

Dilantin Treatment. The mean respiration volumes of subjects per period (see Table 6) are also depicted in Figure 10. Similar to the respiration volumes of the placebo trial, these respiration volumes also increased (in a stair step fashion) with the increase of motion sickness; however, the maximum respiration volume during the dilantin trial occurred one minute after emeisis. Three minutes after emesis, respiration volumes returned to baseline levels.

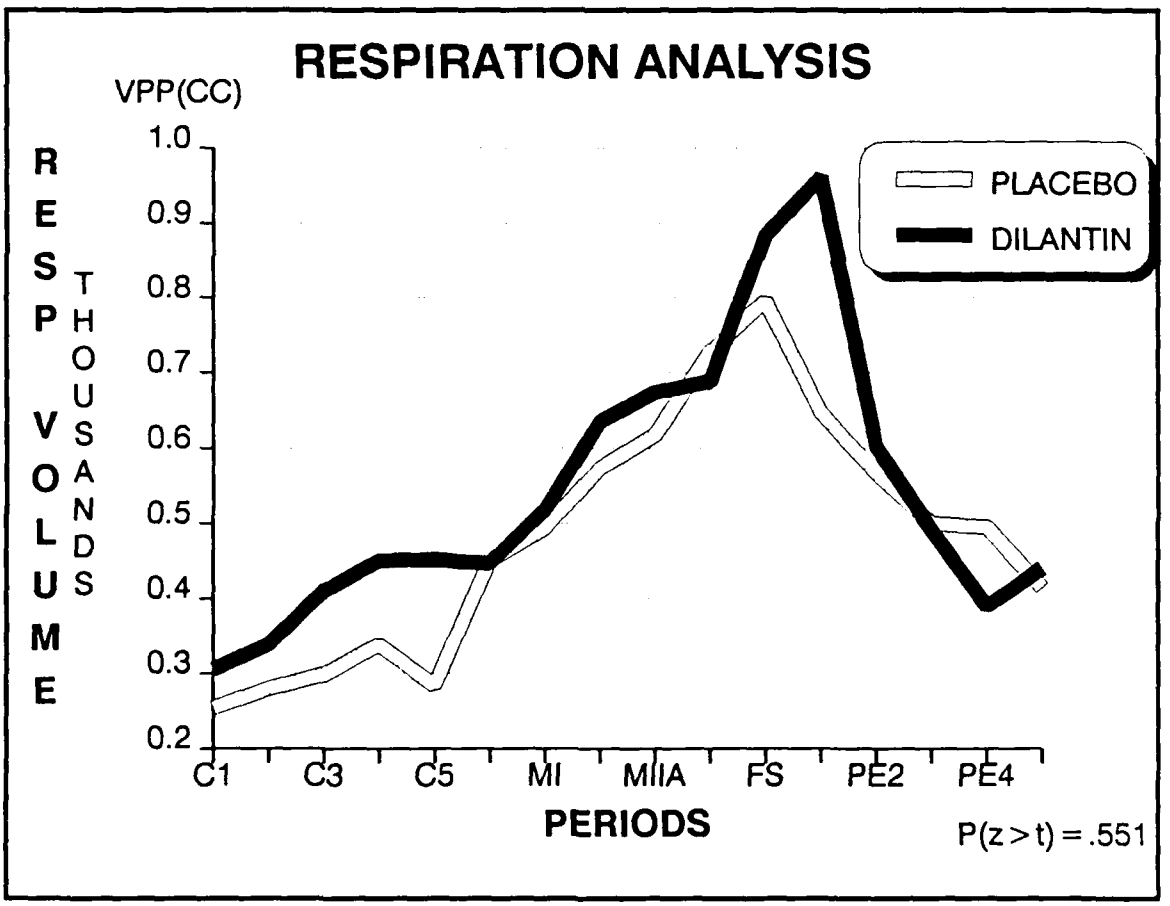

Figure 10 Mean Respiration Volumes of Subjects Treated with Placebo and with Dilantin

Table 5 Mean Respiration Volumes of Subjects Treated with Placebo

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	178	286	231	412	257	165	-	255
CONTROL 2	250	-	244	464	279	165	-	280
CONTROL 3	220	297	411	414	-	155	-	299
CONTROL 4	332	440	317	443	-	161	-	339
CONTROL 5	265	307	205	475	-	170	-	284
ASYMPTOMATIC	521	491	402	659	428	207	447	451
MI	575	354	543	679	466	216	626	494
MIIB	739	500	649	684	487	236	721	574
MIIA	763	488	686	706	590	304	788	618
MIII	905	788	719	645	663	277	1093	727
FRANK SICKNESS	1047	831	790	850	692	246	1115	796
POST EMESIS +1	639	652	610	819	583	247	978	647
POST EMESIS +2	527	439	680	653	742	183	750	568
POST EMESIS +3	450	295	536	559	786	125	748	500
POST EMESIS +4	464	409	409	613	800	146	632	496
POST EMESIS +5	572	266	302	369	610	188	600	415
MEAN PERIODS A-FS	758	575	632	704	554	248	798	

Table 6 Mean Respiration Volumes of Subjects Treated with Dilantin

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	188	200	472	238	515	236	295	306
CONTROL 2	-	204	530	310	482	206	300	339
CONTROL 3	-	442	584	372	454	203	-	411
CONTROL 4	-	628	479	365	550	235	-	451
CONTROL 5	-	500	642	308	536	275	-	452
ASYMPTOMATIC	280	555	673	404	557	250	408	447
MI	425	624	660	181	764	-	461	519
MIIB	563	660	785	-	722	-	450	636
MIIA	571	684	-	-	907	-	533	674
MIII	419	700	-	-	1033	-	600	688
FRANK SICKNESS	575	910	-	-	1350	-	700	884
POST EMESIS +1	533	-	-	-	1389	-	-	961
POST EMESIS +2	236	-	-	-	969	-	-	603
POST EMESIS +3	-	-	-	-	745	-	-	491
POST EMESIS +4	-	-	-	-	639	-	-	390
POST EMESIS +5	-	-	-	-	725	-	-	441
MEAN PERIODS A-FS	472	689	706	293	889	249	525	

Placebo vs. Dilantin. The data suggest that the mean respiration volume of subjects (periods A-FS) treated with the placebo are not significantly different from the mean respiration volume of subjects (periods A-FS) treated with dilantin (alpha = .01, test statistic t = -.6315, DF = 6 and $P(|z| > t) = .5510$)

ESG (VRMS).

Placebo Treatment. The ESG RMS voltages of subjects per period (see Table 7) are depicted in Figure 11. In general, ESG RMS voltages increased with the evolution of motion sickness but reached a maximum at MIIA instead of at frank sickness. The maximum ESG RMS voltages at MIIA was 74% greater than the minimum ESG RMS voltages at control period 3. After MIIA, the ESG RMS voltages gradually dropped but never reached baseline levels.

Dilantin Treatment. The ESG RMS voltages of subjects per period (see Table 8) are depicted in Figure 11. In general, ESG RMS voltages increased with the evolution of motion sickness but reached a maximum at post emesis + 1 instead of at frank sickness. During the evolution of motion sickness, the ESG RMS voltages decreased by 12.2 % during MIII. The maximum ESG RMS voltages at post emesis + 1 was 79 % greater than the minimum ESG RMS voltages at control period 5.

Placebo vs. Dilantin. The data suggest that the ESG RMS voltages for subjects (periods A-FS) treated with the placebo are not significantly different from ESG RMS voltages for subjects (periods A-FS) treated with dilantin (alpha = .01, test statistic t = 1.379, DF = 6 and $P(|z| > t) = .0965$)

Table 7 Root Mean Square Electrosplanchnograph Voltages of Subjects treated with Placebo

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	.13	.0342	-	.0765	-	.0359	.0312	.0616
CONTROL 2	-	.357	-	.0347	.0362	.0314	.0282	.0975
CONTROL 3	-	.0633	-	.0932	.0378	.0349	.0382	.0535
CONTROL 4	-	.133	-	.0551	-	.0323	-	.0735
CONTROL 5	-	.158	-	.0853	-	.0308	-	.0914
ASYMPTOMATIC	.111	.0935	-	.0917	.0377	.0365	.0437	.0690
MI	.134	.0934	.273	.345	.202	.0346	.094	.1680
MIIB	.124	.228	.165	.246	.0715	.248	.244	.1895
MIIA	.115	1.36	.400	.212	.0715	.224	.146	.3612
MIII	.138	.223	.227	.900	.219	.101	.140	.2783
FRANK SICKNESS	.154	.688	.356	.375	.0829	.221	.140	.2881
POST EMESIS +1	.246	.705	.317	.0347	.172	.115	.182	.2531
POST EMESIS +2	.485	.194	.254	.384	.144	.0868	.105	.2361
POST EMESIS +3	-	.139	.259	.328	.115	.0408	.0815	.1606
POST EMESIS +4	-	.366	.150	-	.271	.037	.0726	.1793
POST EMESIS +5	-	.234	.295	-	.107	.0308	.0409	.1415
MEAN PERIODS A-FS	.1293	.4477	.2842	.3616	.1141	.1634	.1650	

Table 8 Root Mean Square Electrosplanchnograph Voltages of Subjects treated with Dilantin

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	.212	.037	.070	.177	.0492	.0351	.0411	.0888
CONTROL 2	.204	.0464	.0539	.0345	.0716	.0377	-	.0747
CONTROL 3	.0807	.0521	.0512	.519	.0496	.040	-	.1321
CONTROL 4	.114	.0419	.0419	.154	.041	.0353	-	.0710
CONTROL 5	.120	.0423	.0423	.0306	.0501	.0387	-	.0525
ASYMPTOMATIC	.157	.062	.117	.306	.0428	.0494	.117	.0823
MI	.102	.372	.117	-	.219	-	.0547	.1729
MIIB	.229	.361	.0368	-	.108	-	.315	.2100
MIIA	.154	.249	-	-	.457	-	.366	.2452
MIII	.126	.248	-	-	.0878	-	.399	.2152
FRANK SICKNESS	.800	.110	-	-	.0443	-	-	.3181
POST EMESIS +1	.893	-	-	-	.0418	-	.0934	.3427
POST EMESIS +2	.189	-	-	-	.0465	-	.0695	.1017
POST EMESIS +3	.514	-	-	-	.0425	-	.0396	.1987
POST EMESIS +4	.140	-	-	-	.076	-	.0818	.0993
POST EMESIS +5	.235	-	-	-	.0364	-	.117	.1295
MEAN PERIODS A-FS	.2613	.2337	.0903	.0306	.1598	.0494	.2503	

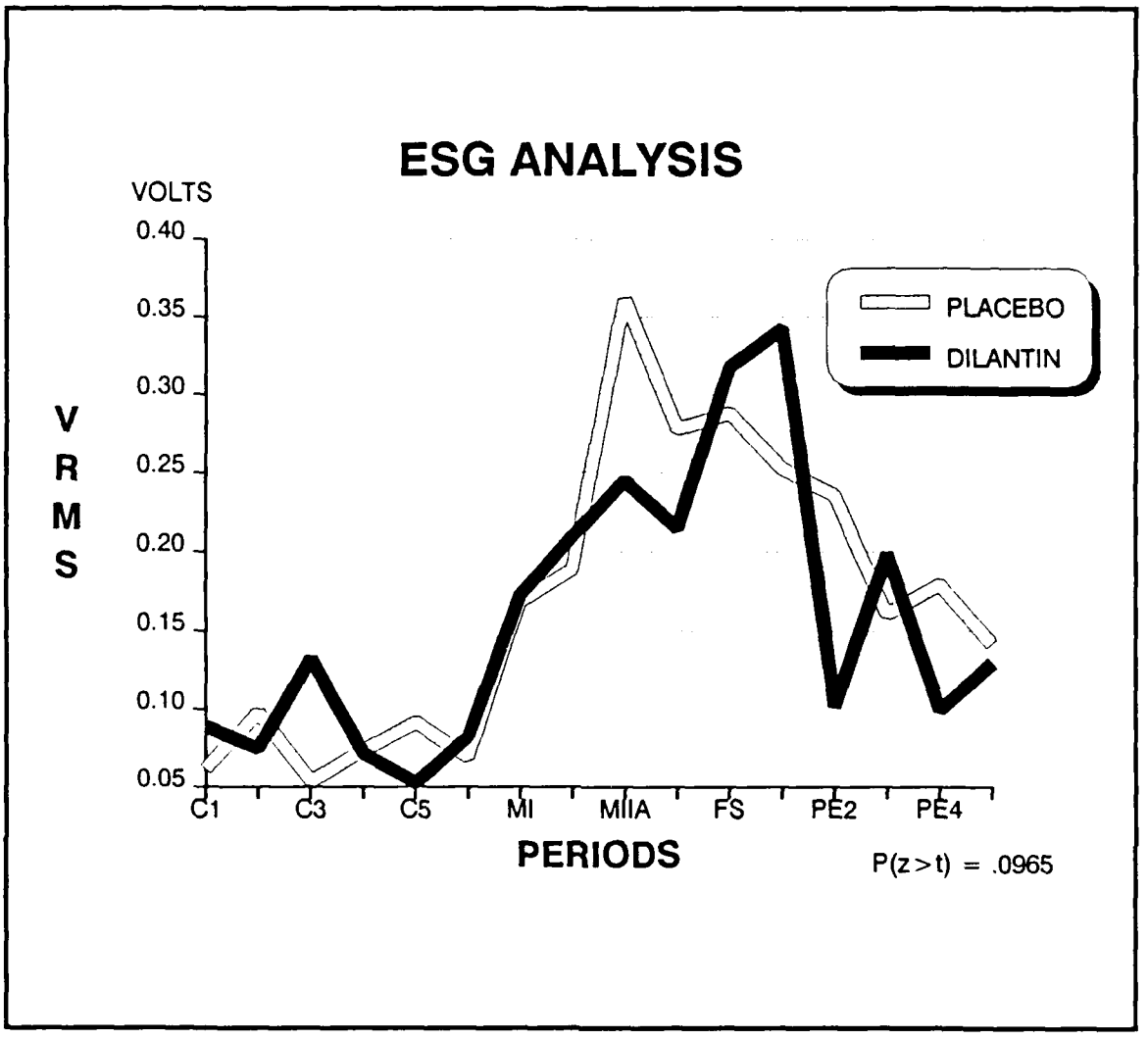

Figure 11 Root Mean Square Electrosplanchnograph Voltages of Subjects treated with Placebo and Dilantin

EEG (VRMS).

Placebo Treatment. The EEG RMS voltages per period (see Table 9) are depicted in Figure 12. The increase in EEG RMS voltages during the control 5 period was due to the unusually high EEG voltages from subject 2. Subject 2 had unusually high EEG RMS voltages for most of the control periods. The EEG RMS

voltages reached their peak at the MIIA period. The maximum EEG RMS voltages at MIIA was 95% greater than the minimum EEG RMS voltages at control period 2. After MIIA the EEG RMS voltages began to decrease with the increase of motion sickness. At one minute and four minutes after emesis the EEG RMS voltages increased slightly. Five minutes after emesis, the EEG RMS voltages never reached baseline levels.

Dilantin Treatment. The EEG RMS voltages per period (see Table 10) are depicted in Figure 12. All subjects had higher EEG RMS voltages during the control periods of the dilantin trial than during the control periods of the placebo trial. This data suggest that dilantin may be increasing the EEG subdelta-delta voltages. The maximum EEG RMS voltages at MIIA were 85% greater than the minimum EEG RMS voltages at control period 2. The EEG RMS voltages from MIIA to MIII decreased 29%, from MIII to frank sickness increased 20% and from frank sickness to post emesis + 1 decreased 83%. Five minutes after emesis the EEG RMS voltage was 46% lower than the control 3 period EEG RMS voltage.

Placebo vs. Dilantin. The data suggest that the EEG RMS voltages for subjects (periods A-FS) treated with the placebo are not significantly different from EEG RMS voltages for subjects (periods A-FS) treated with dilantin (alpha = .01, test statistic t = - 1.0270, DF = 6 and $P(|z| > t) = .8377$)

Table 9 Root Mean Square Electroencephalographs Voltages of Subjects Treated with Placebo

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	2.32	56.9	2.31	2.92	3.41	5.07	1.69	10.66
CONTROL 2	3.88	1.38	1.57	4.3	-	6.42	7.17	4.12
CONTROL 3	-	38.3	2.49	2.87	-	7.33	7.21	11.64
CONTROL 4	-	70.0	1.85	2.68	-	4.85	2.41	16.36
CONTROL 5	-	104	-	-	-	-	2.77	53.39
ASYMPTOMATIC	-	70.5	1.78	30.2	4.18	11.7	13.8	22.03
MI	2.17	68.5	1.17	39.2	4.58	9.43	17.5	20.36
MIIB	.406	2.54	11.9	93.7	4.52	7.10	12.3	18.92
MIIA	-	128	-	129	-	7.50	69.2	83.43
MIII	2.36	15.6	47	134	2.52	8.99	99.2	44.24
FRANK SICKNESS	3.74	13.3	101	101	1.75	11.1	48.7	29.23
POST EMESIS +1	2.77	54.3	216	216	3.65	8.07	72.3	52.78
POST EMESIS +2	87.4	-	17.7	25.5	2.45	3.87	77.7	30.66
POST EMESIS +3	82.1	43.1	24.8	15.9	3.5	4.38	74.8	35.51
POST EMESIS +4	25.6	42.2	44.9	176	7.46	4.88	29.1	47.16
POST EMESIS +5	14.6	125	54.2	4.14	3.88	3.43	14.0	31.32
MEAN PERIODS A-FS	2.17	49.74	17.37	87.85	3.51	9.30	43.45	

Table 10 Root Mean Square Electroencephalograph Voltages of Subjects Treated with Dilantin

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	124	-	24.1	4.26	5.95	6.72	3.04	28.01
CONTROL 2	110	-	42.2	11.1	6.78	2.52	-	34.52
CONTROL 3	41.7	-	27	10.2	9.23	1.65	-	17.96
CONTROL 4	81.6	41.7	8.96	91.4	9.17	-	-	43.79
CONTROL 5	12.9	6.97	38.3	41.7	6.00	1.86	-	17.96
ASYMPTOMATIC	40	40	33.9	17.2	6.05	4.71	4.73	20.94
MI	-	45.9	82.5	15.7	103	4.85	5.6	42.93
MIIB	82	46.0	119	-	39.5	-	4.09	58.12
MIIA	57.4	244	-	-	174	-	1.58	119.24
MIII	74	329	-	-	7.73	-	1.57	84.98
FRANK SICKNESS	63.3	352	-	-	8.1	-	1.4	106.20
POST EMESIS +1	48.2	-	-	-	2.89	-	3.03	18.04
POST EMESIS +2	102	-	-	-	4.33	-	7.22	37.85
POST EMESIS +3	27.3	-	-	-	26.4	-	25.31	19.67
POST EMESIS +4	55	-	-	-	24.9	-	3.66	27.85
POST EMESIS +5	22.7	-	-	-	2.28	-	3.86	9.61
MEAN PERIODS A-FS	63.34	176.15	78.47	16.45	56.40	4.85	3.16	

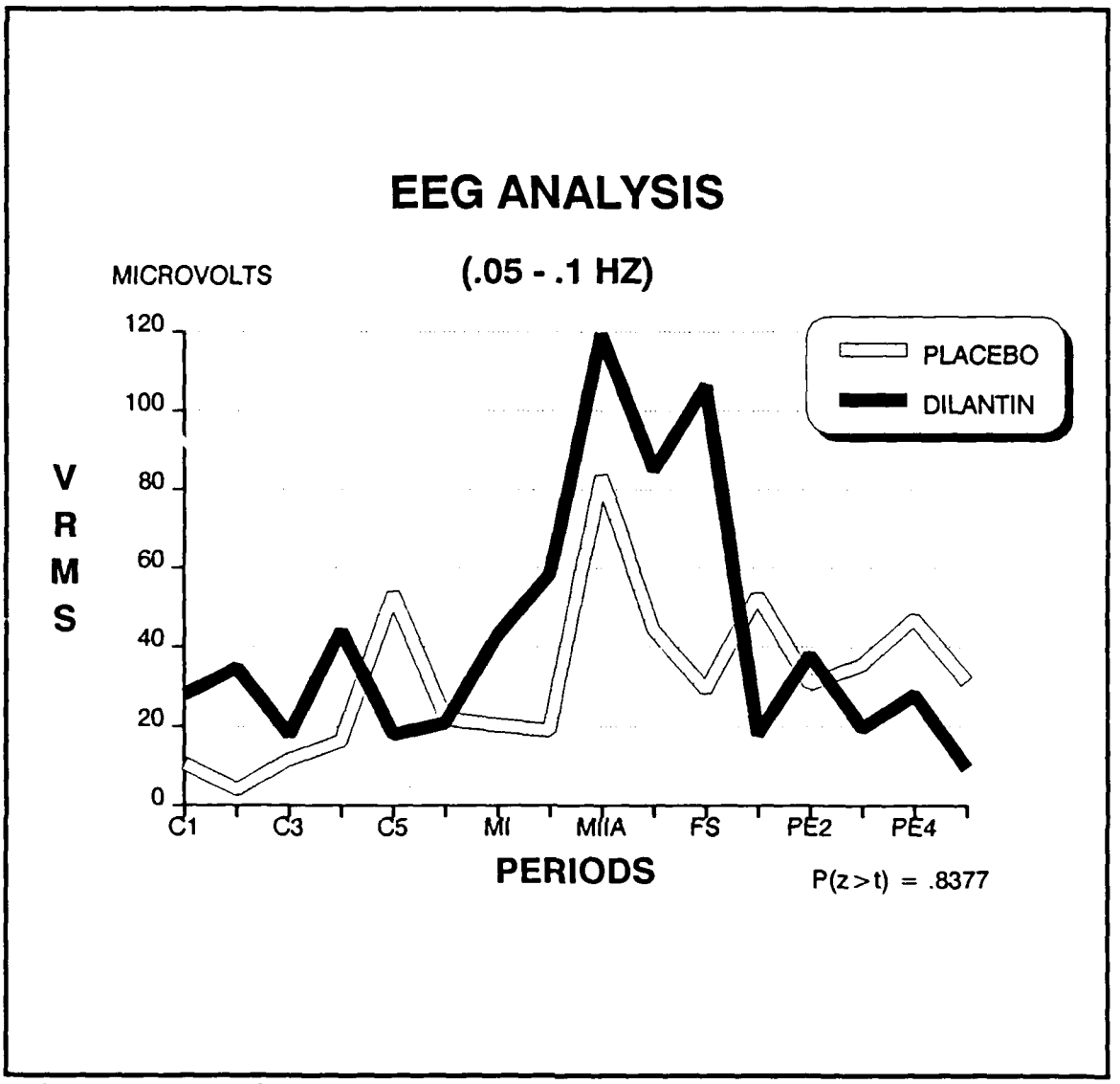

Figure 12 Root Mean Square Electoencephalograph Voltages of Subjects Treated with Placebo and Dilantin

EEG (Peak Voltages).

Placebo. The EEG peak voltages per period (see Table 11) are depicted in Figure 13. The increase in EEG peak voltages during the control 5 period was due the unusually high EEG voltages from subject 2. Subject 2 had unusually high EEG peak voltages for most of the control periods. The EEG peak voltages reached their

peak at the MIIA period. The maximum EEG peak voltages at MIIA were 92% greater than the minimum EEG peak voltages at control period 5. After MIIA the EEG peak voltages began to decrease with the increase of motion sickness. The EEG peak voltages from MIIA to frank sickness decreased 56%. At one minute and four minutes after emesis the EEG peak voltages increased slightly. By the end of the PE + 5 period, the EEG peak voltages had not reached baseline levels.

Dilantin Treatment. The EEG peak voltages per period (see Table 12) are depicted in Figure 13. Six of the seven subjects had higher EEG peak voltages during the control 1 period of the dilantin trial than the control 1 period of the placebo trial. Subject 2 had no EEG peak voltage during the control 1 period. Similar to the EEG RMS voltages, this data suggest that dilantin may be increasing the EEG subdelta-delta voltages. The maximum EEG peak voltage at MIIA was 82.2% greater than the minimum EEG peak voltage at the control 5 period. The EEG RMS voltages from MIIA to MIII decreased 18%, from MIII to frank sickness decreased 6% and from frank sickness to the post emesis + 1 period decreased 79%. Five minutes after emesis, the EEG peak voltage was 46% lower than the control 5 period EEG peak voltage.

Placebo vs Dialntin. The data suggest that the EEG peak voltages for subjects (periods A-FS) treated with the placebo are not significantly different from EEG peak voltages for subjects (periods A-FS) treated with dilantin (alpha = .01, test statistic t = .3792, DF = 6 and $P(|z| > t) = .7176$).

Table 11 Peak Electrocephalograph Voltages of Subjects Treated with Placebo

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	12.83	171.9	9.98	13.33	16.87	27.99	9.51	43.74
CONTROL 2	20.89	43.4	5.94	27.30	-	26.80	33.5	26.31
CONTROL 3	-	149.22	10.7	15.68	-	31.80	26.90	46.86
CONTROL 4	-	157.7	6.4	17.58	-	21.59	13.28	43.31
CONTROL 5	-	383	-	26.70	-	-	16.87	142.19
ASYMPTOMATIC	-	303	5.96	27.91	20.71	58.7	68.7	122.69
MI	9.98	304	5.23	160.6	20.67	61.3	120	113.63
MIIB	18.02	10.69	46.3	414	22.08	34.5	61.5	101.18
MIIA	-	341	280	461	-	38.7	424	316.18
MIII	12.83	49.7	84.8	542	13.07	59.4	419	229.33
FRANK SICKNESS	17.59	54.9	64.8	374	9.50	49.4	197.7	139.57
POST EMESIS +1	14.0	198	64.8	789	21.9	34.50	413	255.87
POST EMESIS +2	310.7	-	92.4	86.0	13.54	22.80	409	186.88
POST EMESIS +3	270	193.2	116.2	65.6	17.10	19.49	319	166.77
POST EMESIS +4	25.6	187.4	202.7	504	32.80	28.10	200	196.77
POST EMESIS +5	14.6	435	220	-	18.51	17.31	57	152.48
MEAN PERIODS A-FS	14.61	172.22	84.46	503.28	21.59	56.08	272.53	

Table 12 Peak Electroencephalograph Voltages of Subjects Treated with Dilantin

PERIOD	SUB 1	SUB 2	SUB 3	SUB 4	SUB 5	SUB 6	SUB 7	MEAN SUB 1-7
CONTROL 1	476	-	121.2	21.84	34.0	36.1	15.44	117.43
CONTROL 2	386	-	201.3	51.8	35.4	14.97	-	137.89
CONTROL 3	189	-	98.8	61.3	41.1	9.26	-	79.89
CONTROL 4	295	113.6	39.5	413	45.9	-	-	181.4
CONTROL 5	39.4	37.6	151.3	150.4	33.7	12.83	-	70.87
ASYMPTOMATIC	213.0	160.6	159.9	76.3	30.2	33.5	21.82	115.89
MI	-	197.4	297.0	92.2	492.0	-	22.3	220.18
MIIB	233	168	378.0	-	189.6	-	18.79	197.48
MIIA	180.3	776	-	-	632.0	-	7.13	398.86
MIII	270	973	-	-	54.4	-	7.61	326.25
FRANK SICKNESS	211.3	973	-	-	40.4	-	1.41	306.53
POST EMESIS +1	158.2	-	-	-	16.4	-	17.59	64.06
POST EMESIS +2	405.0	-	-	-	20.67	-	25.0	150.22
POST EMESIS +3	114.0	-	-	-	99.1	-	21 8	78.3
POST EMESIS +4	339.0	-	-	-	112.9	-	17.8	156.57
POST EMESIS +5	86.7	-	-	-	13.07	-	15.44	38.40
MEAN PERIODS A-FS	221.5	541.3	278.3	84.25	237.47	33.5	16.11	

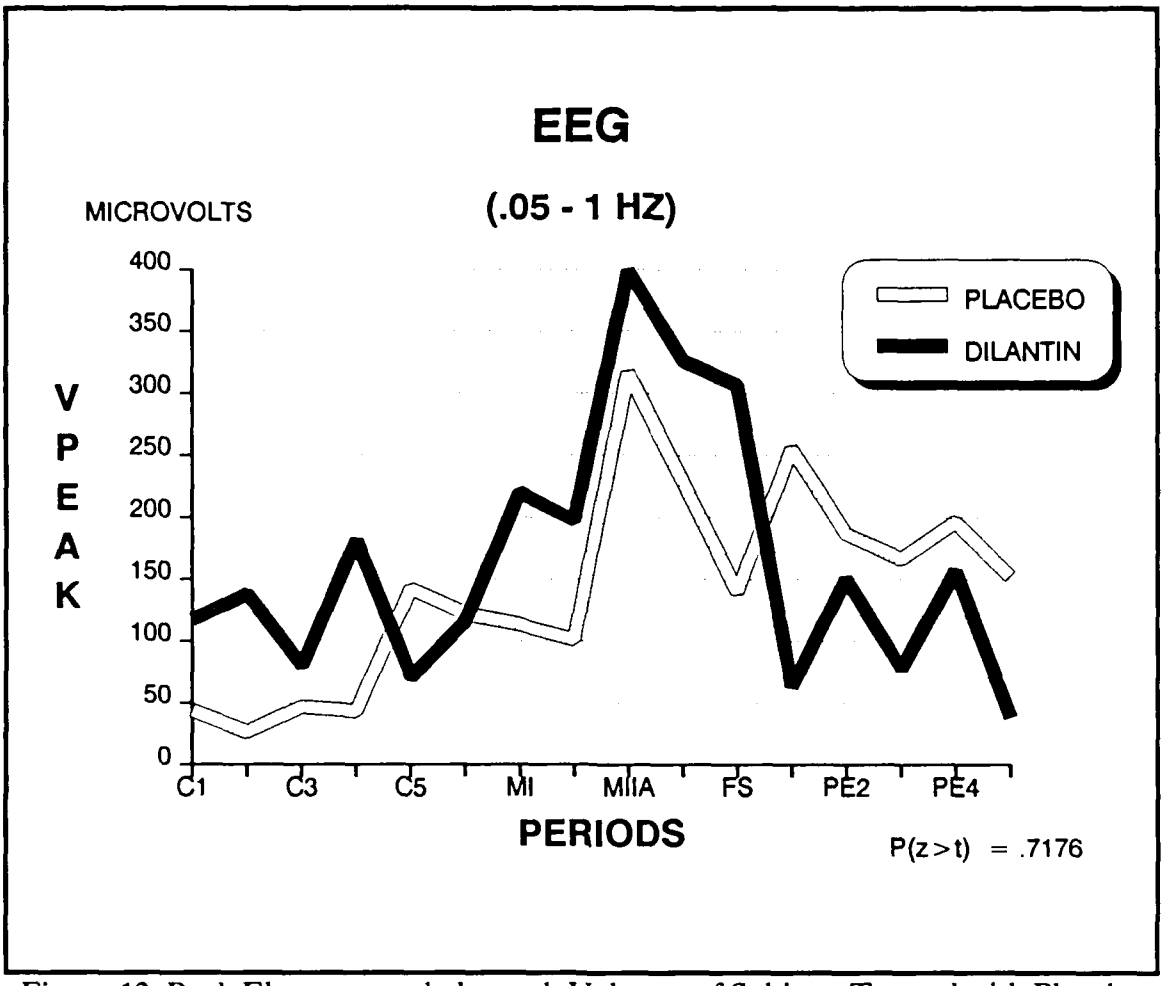

Figure 13 Peak Electroencephalograph Voltages of Subjects Treated with Placebo and Dilantin

Performance-Cognitive Tests

Probability Monitoring Task. The scores of the subjects on placebo are identified in Table 13 and the scores of the subjects on dilantin are identified in Table 14. The data suggest that the probability monitoring task scores for subjects treated with the placebo are not significantly different from the probability monitoring task scores for subjects treated with dilantin (alpha = .01, test statistic t = -.5669, DF = 6 and $P(|z| > t) = .5913$).

Table 13 Probability Monitoring Scores of Subjects Treated with Placebo

SUBJECT	CORRECT	FALSE RESPONSES	MISSED BIASES	MEAN RESPONSE TIME
1	10	12	0	2.1
2	10	10	0	2.7
3	10	2	0	2.1
4	10	0	0	4.3
5	10	0	0	3
6	10	8	0	2.9
7	10	6	0	3.2

Table 14 Probability Monitoring Scores of Subjects Treated with Dilantin

SUBJECT	CORRECT	FALSE RESPONSES	MISSED BIASES	MEAN RESPONSE TIME
1	10	20	0	2.6
2	10	8	0	2.8
3	10	0	0	4.5
4	10	2	0	4.3
5	10	1	0	2.8
6	10	12	0	2.8
7	9	4	1	2.8

Grammatical Reasoning Task. The scores of the subjects on placebo are identified in Table 15 and the scores of the subjects on dilantin are identified in Table 16. The data suggest that the grammatical reasoning task scores for subjects treated with the placebo are not significantly different from the grammatical reasoning scores for subjects treated with dilantin (alpha = .01, test statistic t = -.9101, DF = 6 and $P(|z| > t) = .3979$).

Table 15 Grammatical Reasoning Scores of Subjects Treated with Placebo

SUBJECT	STIMULI	CORRECT	TOTAL INCORRECT	ERROS	MISSED	MEAN RESPONSE TIME
1	58	58	0	0	0	2476.81
2	53	41	12	0	0	2662.49
3	40	38	2	2	0	3923.39
4	25	25	0	0	0	6284.68
5	48	46	2	2	0	3089.46
6	49	48	1	1	0	3030.96
7	54	50	4	4	0	2662.74

Table 16 Grammatical Reasoning Scores of Subjects treated with Dilantin

SUBJECT	STIMULI	CORRECT	TOTAL INCORRECT	ERROS	MISSED	MEAN RESPONSE TIME
1	63	60	3	3	0	2206
2	52	48	4	4	0	2724.98
3	43	42	1	1	0	3476
4	32	31	1	1	0	4991.52
5	48	46	2	2	0	3082
6	42	39	3	3	0	3707.62
7	49	49	0	0	0	2996.37

Unstable Tracking Task. The scores of the subjects on placebo are identified in Table 17 and the scores of the subjects on dilantin are identified in Table 18. The data suggest that the unstable tracking scores for subjects treated with the placebo are not significantly different from the unstable tracking scores for subjects treated with dilantin (alpha = .01, test statistic t = .5664, DF = 6 and $P(|z| > t) = .5916$).

Table 17 Unstable Tracking Scores of Subjects Treated with Placebo

SUBJECT	RMS	EDGE VIOLATIONS
1	40.6	32
2	42.5	47
3	15.3	0
4	30.7	2
5	40.0	39
6	34.5	16
7	44.2	95

Table 18 Unstable Tracking Scores of Subjects Treated with Dilantin

SUBJECT	RMS	EDGE VIOLATIONS
1	46.3	68
2	44.9	84
3	12.9	0
4	46.9	80
5	34.6	34
6	34.1	20
7	39.4	62

Trial Time

The trial time of subjects treated with the placebo and the trial time of subjects treated with dilantin are identified in Table 19 and depicted in Figure 14. Subjects 3, 4 and 6 never reached the MIIA period and, they eventually adapted to the motion stimulus. The remaining subjects eventually reached emesis. The data suggest that the subjects treated with the dilantin were significantly more tolerant to motion stimulus than subjects treated with the placebo (alpha = .01, test statistic t = -3.4539, DF = 6 and $P(Z<t) = .0026$).

Table 19 Trial times of Subjects Treated with Placebo and Dilantin,and Dilantin Blood Serum Levels

SUBJECT	PLACEBO TRIAL TIME (MINUTES)	DILANTIN TRIAL TIME (MINUTES)	DILANTIN BLOOD SERUM LEVEL
1	2	6	14.7
2	4	42	12.0
3	13	90	12.3
4	26	97	12.3
5	7	26	14.0
6	8	80	12.4
7	14	54	13.0

NOTE: SUBJECTS 3, 4 AND 6 NEVER REACHED MIIA.

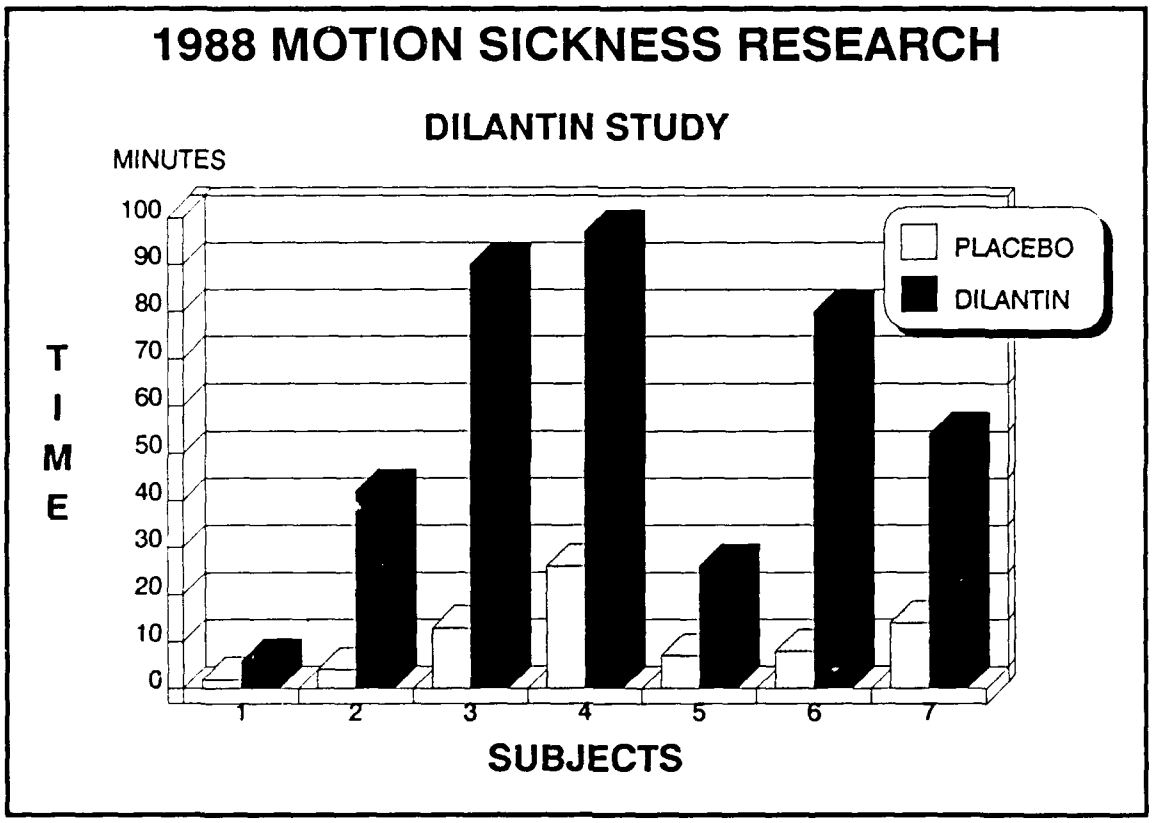

Figure 14 1988 Dilantin Study Results

Dilantin Blood Levels

The dilantin blood levels of subjects treated with the dilantin are identified in Table 19 and depicted in Figure 15. As mentioned earlier, subjects 3, 4, and 6 adapted to the motion stimulus, and they had dilantin blood levels of 12.4, 12.3 and 12.3 *(microgram per milliliter) respectively.* The remaining subjects eventually reached emesis and had blood levels outside the 12.3 - 12.4 range. The data suggest that the therapeutic motion sickness prevention range might be between 12.3 - 12.4 (alpha = .01, test statistic t = 1.6550, DF = 6 and $P(|z| > t) = .1490$). The small size of the test population; however, requires that this conclusion be considered extremely tentative; indeed it seems, at face value, to be somewhat improbable.

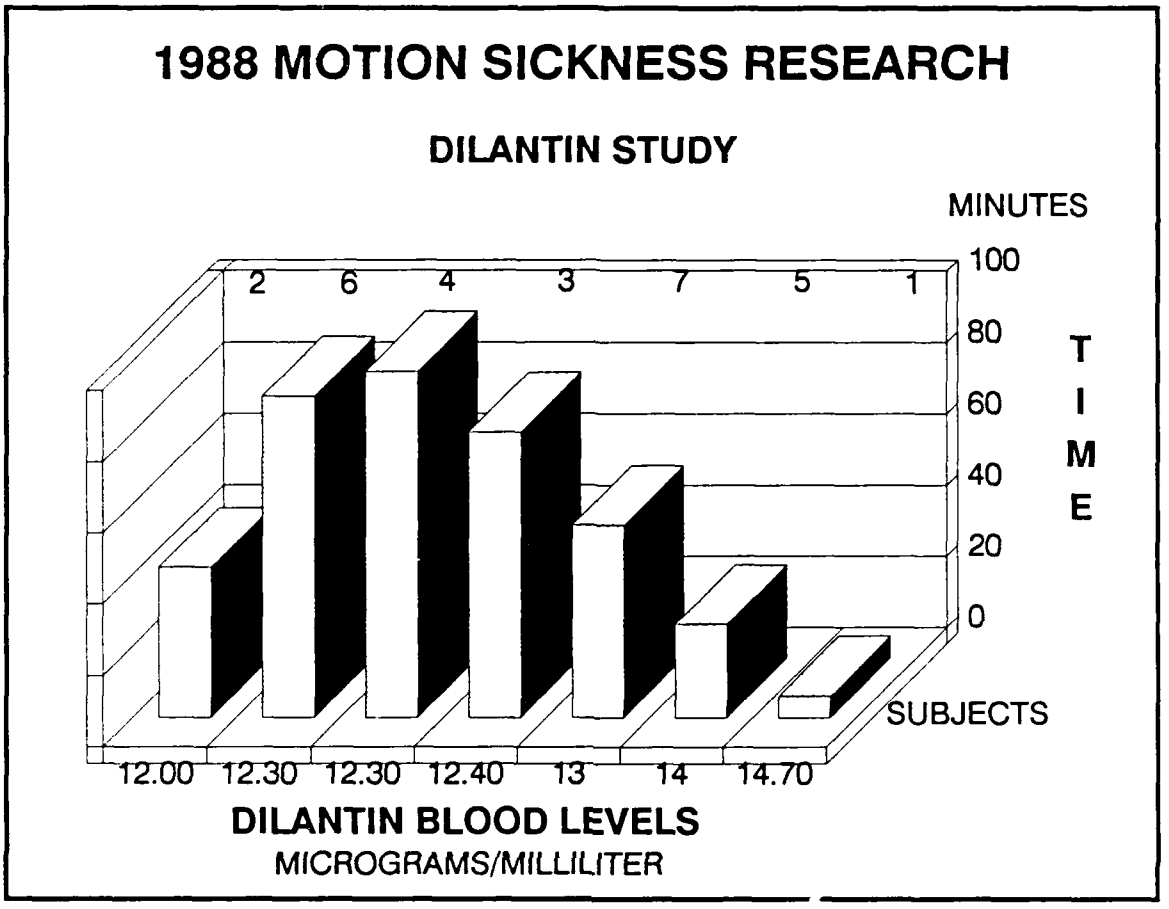

Figure 15 Dilantin Blood Serum Levels of Subjects

1987 and 1988 Dilantin Research

The combined 1987 and 1988 trial times of subjects treated with the placebo and the trial time of subjects treated with dilantin are depicted in Figure 16. The data suggest that the subjects treated with the dilantin were significantly more tolerant to motion stimulus than subjects treated with the placebo (alpha = .01, test statistic t = -5.5805, DF = 8 and $P(Z < t) = .0003$).

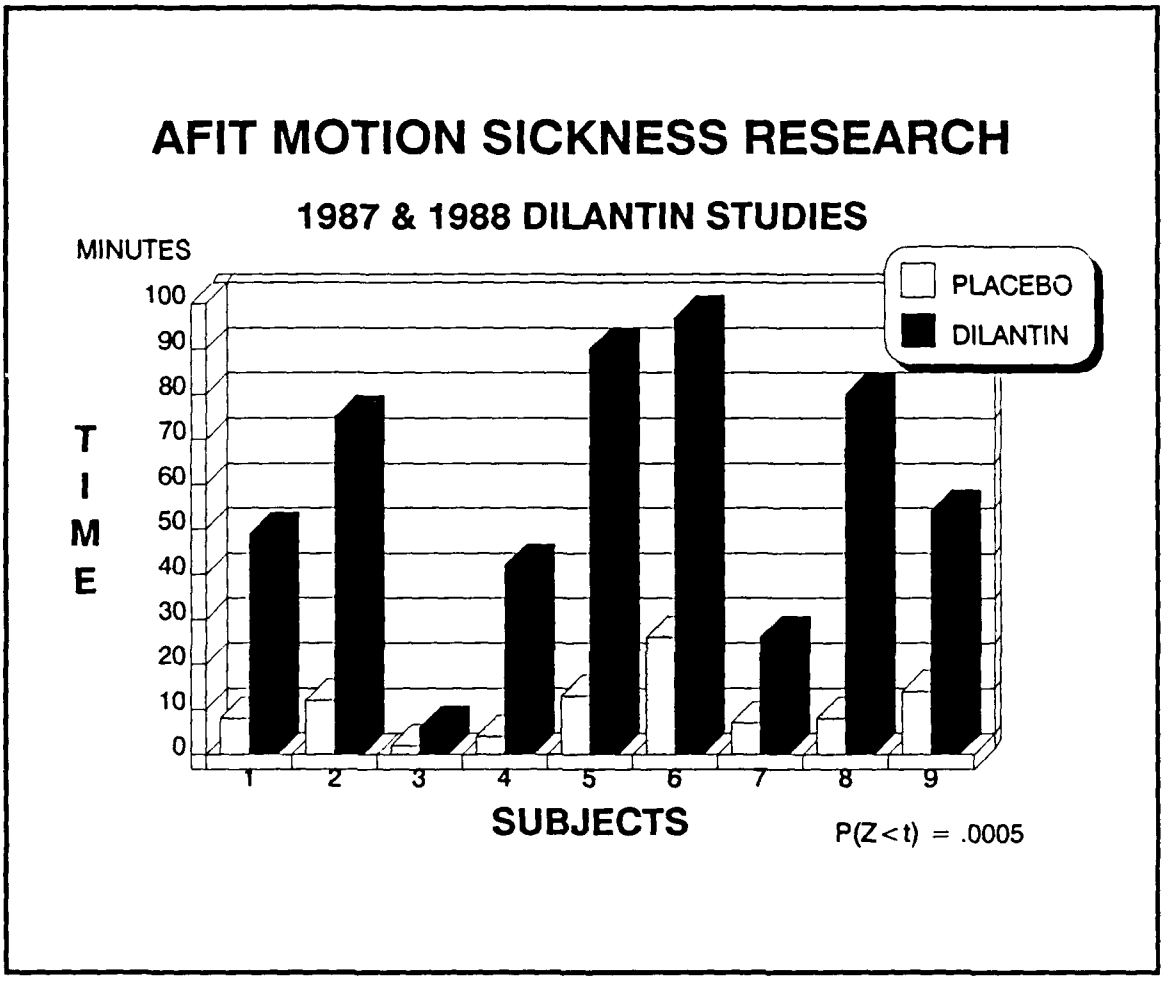

Figure 16 1987 and 1988 Dilantin Results

V. Modeling

This chapter describes and reports the results of: 1) a polynomial based neural network used to model motion sickness and to predict motion sickness; and 2) a linear regression model used to predict motion sickness. This chapter also describes how either method could be used to predict space motion sickness preflight.

Neural Network

This research used the Abductive Reasoning Mechanism (ARM) software provided by Barron Associates to model motion sickness and to predict motion sickness (7). This set of computer programs relies on the concepts of abduction and polynomial network theory. Abductive reasoning is distinguishable from both inductive and deductive reasoning. Abduction is defined as the "the act or process of reasoning from a set of general principles to particulars or general principles under certainty" (35:22). Thus, it works in the same manner as deduction, and in the reverse direction of inductive reasoning, since the latter goes "from a set of principles and particulars to general particulars" (35:22). Deduction requires that a relationship must exist among separate sets of data. On the other hand, abduction needs only a "consistency of the relationships among independent observations of data"; the exact nature of the relationships can be unknown (35:22). The syllogism is the basic form of deductive reasoning, while abductive reasoning uses abductive functions. An abductive function is defined as "any function representing the relationships of a set of input variables to set of outputs" (35:22). The ARM software relies on an Algorithm for Synthesis of Polynomial Networks (ASPN). ASPN models any function as a layered network of polynomial elements.

This process is in conformance with Kolmogorv's representation theorem, which has been restated by A.R. Barron as, "four-layer networks can represent any function provided elements are allowed which implement arbitrary continuous functions of one variable as well as elements which simply implement the sum of several variables" (35:34).

The network created by ASPN is called an abductively-synthesized polynomial network or abductive polynomial network (APN) with "each node in the network representing a polynomial equation with the coefficients and network connectivity learned" (35:36). The APN is synthesized after "a tradeoff between model complexity and accuracy, with the assumption that model simplicity will improve the likelihood of closely fitting unseen (new) data" (35:36).

Motion Sickness Models. Models were developed using data from the placebo trials and dilantin trials. The Data consisted of five minutes of baseline (C1-C5) data, asymptomatic period data, malaise period data (MI, MIIB, MIIA, MIII, frank sickness), and five minutes of post emesis data (PE1-PE5). Table 20 shows these periods converted to motion sickness levels 1 to 16. This research used ARM to develop individual EKG, respiration, ESG, and EEG models to determine levels of motion sickness. ARM was also used to develop a combined EKG, respiration, ESG, and EEG model to determine levels of motion sickness. Entering a parameter or parameters into the model resulted in an output of a motion sickness level (1 - 16).

EKG Models.

Placebo. Using EKG data (see Table 3), the following equation was derived relating the level of motion sickness to heart rate.

$$\text{Level} = (6255.21) - (521.794) * (\text{EKG}) + (17.5175) * (\text{EKG}^2) - (0.302651) * (\text{EKG}^3) + (2.831000\text{e-}03) * (\text{EKG}^4) - (1.400000\text{e-}05) * (\text{EKG}^5) \quad (2)$$

where

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

EKG = Electrocardiograph Data (Beats Per Minute)

Modeling statistics are shown in Table 20.

Dilantin. Using EKG data (see Table 4), the following equation was derived relating the level of motion sickness to heart rate.

$$\text{Level} = (-1.9116666\text{e}+09) + (3.075310\text{e}+08) * (\text{EKG}) - (2.2586\text{e}+07) * (\text{EKG}^2) + (1.001440\text{e}+06) * (\text{EKG}^3) - (29854.8) * (\text{EKG}^4) + (630.458) * (\text{EKG}^5) - (9.67053) * (\text{EKG}^6) + (.1085665) * (\text{EKG}^7) - (8.850000\text{e-}04) * (\text{EKG}^8) + (5.000000\text{e-}06) * (\text{EKG}^9) \quad (3)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

Table 20 EKG Placebo Modeling Statistics and Level Conver.

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	8.04819
	SIGMA	4.24804
	MIN	1
	MAX	16
INPUT VARIABLE "EKG"	MEAN	73.5531
	SIGMA	9.07103
	MIN	53.5408
	MAX	95.3062

PERIOD TO LEVEL CONVERSION

C1 = 1	A = 6	PE1 = 12
C2 = 2	MI = 7	PE2 = 13
C3 = 3	MIIB = 8	PE3 = 14
C4 = 4	MIIA = 9	PE4 = 15
C5 = 5	MIII = 10	PE5 = 16
	FS = 11	

EKG = Electrocardiograph Data (Beats Per Minute)

Modeling statistics are shown in Table 21.

Table 21 EKG Dilantin Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	6.91935
	SIGMA	4.24757
	MIN	1
	MAX	16
INPUT VARIABLE "EKG"	MEAN	68.2024
	SIGMA	8.64707
	MIN	54.62
	MAX	99.61

Respiration.

Placebo. Using respiration data (see Table 5), the following equation was derived relating the level of motion sickness to respiration volume.

Table 22 Respiration Placebo Modeling Statitics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	8.96117
	SIGMA	4.50657
	MIN	1
	MAX	16
INPUT VARIABLE "RESP"	MEAN	597.514
	SIGMA	1065.54
	MIN	127.78
	MAX	11115.2

$$Q1 = 0 + .628868(x-4.2923497e-02)^{1/3} \quad (4)$$

where:

$$x = (-.871068) + (1.84600e-03) * (RESP) \quad (5)$$

$$Level = 8.96117 + (4.50657) * (Q1) \quad (6)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

RESP = Respiration Data (Breaths Per Volume)

Modeling statistics are shown in Table 22.

Dilantin. Using respiration data (see Table 6), the following equation was derived relating the level of motion sickness to respiration volume.

$$Level = (40.4542) - (0.251188) * (RESP)$$

$$-(2.71e-04) * (RESP^2) + (8e-06) * (RESP^3)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

RESP = Respiration Data (Breaths Per Volume)

Modeling statistics are shown in Table 23.

Table 23 Respiration Dilantin Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	6.97143
	SIGMA	4.21891
	MIN	1
	MAX	16
INPUT VARIABLE "RESP"	MEAN	506.592
	SIGMA	256.719
	MIN	140
	MAX	1388.89

Electrosplanchnograph.

Placebo. Using ESG data (see Table 7), the following equation was derived relating the level of motion sickness to ESG voltages.

$$\text{Level} = (4.34128) + (53.5669) * (\text{ESG}) - (133.966) * (\text{ESG}^2) + (136.935) * (\text{ESG}^3) - (49.0338) * (\text{ESG}^4) \quad (7)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

ESG = Electrosplanchnograph Data (VRMS)

Table 24 ESG Placebo Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	8.98913
	SIGMA	4.39489
	MIN	1
	MAX	16
INPUT VARIABLE "ESG"	MEAN	.180848
	SIGMA	.19617
	MIN	.0282
	MAX	1.36

Modeling statistics are shown in Table 24.

Dilantin. Using ESG data (see Table 8), the following equation was derived relating the level of motion sickness to ESG voltages.

$$\text{Level} = (6.38908) + (6.148322) * (\text{ESG}) \quad (9)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

ESG = Electrosplanchnograph Data (VRMS)

Modeling statistics are shown in Table 25.

Table 25 ESG Dilantin Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE 'LEVEL'	MEAN	7.26316
	SIGMA	4.45554
	MIN	1
	MAX	16
INPUT VARIABLE 'ESG'	MEAN	.142166
	SIGMA	.165241
	MIN	.0255
	MAX	.893

Electroencephalograph.

Placebo. Using EEG data (see Table 9 and 11), the following equation was derived relating the level of motion sickness to EEG voltages.

$$\text{Level} = (5.00591) + (.58563) * (\text{RMSEEG}) - (1.7434\text{e-}02) * (\text{RMSEEG}^2) + (2.17\text{e-}04) * (\text{RMSEEG}^3) - (1.000\text{e-}06) * (\text{RMSEEG}^4) \quad (10)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

RMSEEG = Electroencephalograph Data (Root Mean Square Voltages)

Modeling statistics are shown in Table 26.

$$\text{Level} = -(6.671910) + (2.62302) * (\text{PEAKEEG}) - (.179487) * (\text{PEAKEEG}^2) + (5.998\text{e-}03) * (\text{PEAKEEG}^3) - (1.13\text{e-}04) * (\text{PEAKEEG}^4) + (1.00\text{e-}06) * (\text{PEAKEEG}^5) \quad (11)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

PEAKEEG = Electroencephalograph Data (PeakVoltages)

Table 26 RMS-EEG Placebo Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	8.80412
	SIGMA	4.64767
	MIN	1
	MAX	16
INPUT VARIABLE "RMS-EEG"	MEAN	30.7935
	SIGMA	42.2032
	MIN	1.17
	MAX	216

Table 27 Peak-EEG Placebo Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	8.80412
	SIGMA	4.64767
	MIN	1
	MAX	16
INPUT VARIABLE "PEAK-EEG"	MEAN	126.106
	SIGMA	157.775
	MIN	4.34
	MAX	789

Modeling statistics are shown in Table 27

Dilantin. Using EEG data (see Table 10 and 12), the following equation was derived relating the level of motion sickness to EEG voltages.

$$\text{Level} = (7.41691) - (2.973000e\text{-}03) * (\text{RMSEEG}) + (3.4000e\text{-}05) * (\text{RMSEEG}^2) \quad (12)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

RMSEEG = Electroencephalograph Data (Root Mean Square Voltages)

Modeling statistics are shown in Table 28.

$$\text{Level} = (7.74263) - (5.61000e\text{-}03) * (\text{PEAKEEG}) + (9.000e\text{-}06) * (\text{PEAKEEG}^2) \quad (13)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

PEAKEEG = Electroencephalograph Data (Peak Voltages)

Modeling statistics are shown in Table 29.

Table 28 RMS-EEG Dilantin Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	7.35211
	SIGMA	4.47559
	MIN	1
	MAX	16
INPUT VARIABLE "RMS-EEG"	MEAN	43.5948
	SIGMA	67.046
	MIN	1.4
	MAX	352

Table 29 Peak-EEG Dilantin Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	7.44286
	SIGMA	4.44212
	MIN	1
	MAX	16
INPUT VARIABLE "PEAK-EEG"	MEAN	164.106
	SIGMA	209.503
	MIN	5.71
	MAX	973

Motion Sickness Model.

Placebo. Using EKG, respiration, ESG,and EEG data (see Appendix B), the following nonlinear equation was derived relating the level of motion sickness to these physiological parameters.

$$
\begin{aligned}
\text{Level} = {} & (-9.583924e+06) + (1.104090e+06) * (EKG) \\
& + (1260.99) * (RESP) - (1.064224e+07) * (ESG) \\
& - (56356.4) * (EKG^2) - (76.2067) * (\dot{RESP}) \\
& - (5.56043) * (RESP^2) + (932401) * (EKG) * (ESG) \\
& + (15088) * (RESP) * (ESG) - (3.767856e) * (ESG^2) \\
& + (1672.51) * (EKG^3) + (1.49366) * (EKG^2) * (RESP) \\
& + (.422921) * (EKG) * (RESP2) + (3.238e-03) * (RESP^3) \\
& - (3.4871.5) * (EKG^{ESG}) \\
& - (1273.73) * (EKG) * (RESP) * (ESG) \\
& - (5.34147) * (RESP^2) * (ESG) + (223432) * (EKG) * (ESG^2) \\
& + (10629.9) * (RESP) * (ESG^2) - (359913) * (ESG^3) \\
& - (31.7956) * (ESG^4) - (1.281E-03) * (EKG^3) * (RESP) \\
& - (1.3428e-02) * (EKG^2) * (RESP^2) \\
& - (2.22E-04) * (EKG) * (RESP^3) - (1.00e-06) * (RESP^4) \\
& + ((721.374) * (EKG^3) * (ESG) \\
& + (46.6988) * (EKG^2) * (RESP) * (ESG) \\
& + (.241221) * (EKG^2) * (RESP^2) * (ESG)
\end{aligned}
$$

$$+ (7.66e\text{-}03) * (RESP^3) * (ESG)$$

$$- (5235.07) * (EKG^2) * (ESG^2)$$

$$- (631.744) * (EKG) * (RESP) * (ESG^2)$$

$$- (8.11251) * (RESP^2) * (ESG^2)$$

$$+ (9607.52) * (EKG) * (ESG^3)$$

$$+ (1763.78) * (RESP) * (ESG^3) + (22207.6) * (ESG^4)$$

$$+ (.401416) * (EKG^5) - (3.69e\text{-}04) * (EKG^4) * (RESP)$$

$$+ (2.77e\text{-}04) * (EKG^3) * (RESP^2)$$

$$+ (7.0e\text{-}06) * (EKG^2) * (RESP^3)$$

$$- (8.91022) * (EKG^4) * (ESG)$$

$$- (.959891) * (EKG^3) * (RESP) * (ESG)$$

$$- (3.791e\text{-}03) * (EKG^2) * (RESP^2) * (ESG)$$

$$- (3.66e\text{-}04) * (EKG) * (RESP^3) * (ESG)$$

$$- (3.0e\text{-}06) * (RESP^4) * (ESG)$$

$$+ (60.0826) * (EKG^3) * (ESG^2)$$

$$+ (15.1015) * (EKG^2) * (RESP) * (ESG^2)$$

$$+ (.437561) * (EKG) * (RESP^2) * (ESG^2)$$

$$+ (2.653e\text{-}03) * (RESP^3) * (ESG^2)$$

$$- (57.9463) * (EKG^2) * (ESG^3)$$

$$- (55.1866) * (EKG) * (RESP) * (ESG^3)$$

$$- (2.54296) * (RESP^2) * (ESG^3)$$

$$- (464.707) * (EKG) * (ESG^4)$$

$$- (61.669) * (RESP) * (ESG^4) - (369.852) * (ESG^5)$$

$$- (3.364e\text{-}03) * (EKG^6) + (6.0e\text{-}06) * (EKG^5) * (RESP)$$

$$- (2.0e\text{-}06) * (EKG^4) * (RESP^2)$$

$$+ (6.5682e\text{-}02) * (EKG^5) * (ESG)$$

$$+ (1.1888e\text{-}02) * (EKG^4) * (RESP) * (ESG)$$

$$+ (2.0e\text{-}05) * (EKG^3) * (RESP^2) * (ESG)$$

$$+ (7.0e\text{-}06) * (EKG^2) * (RESP^3) * (ESG)$$

$$- (.329606) * (EKG^4) * (ESG^2)$$

$$- (.180296) * (EKG^3) * (RESP) * (ESG^2)$$

$$- (1.009e\text{-}02) * (EKG^2) * (RESP^2) * (ESG^2)$$

$$- (5.3e\text{-}05) * (EKG) * (RESP^3) * (ESG^2)$$

$$- (2.0e\text{-}06) * (RESP^4) * (ESG^2) - (.293944) * (EKG^3)$$

$$+ (.541069) * (EKG^2) * (RESP) * (ESG^3)$$

$$+ (8.4662e\text{-}02) * (EKG) * (RESP^2) * (ESG^3)$$

$$+ (1.097e\text{-}03) * (RESP^3) * (ESG^3)$$

$$+ (2.24088) * (EKG^2) * (ESG^4)$$

$$+ (1.35259) * (EKG) * (RESP) * (ESG^4)$$

$$+ (4.0835e\text{-}02) * (RESP^2) * (ESG^4)$$

$$+ (4.0087) * (EKG) * (ESG^5)$$

$$+ (.491753) * (RESP) * (ESG^5)$$

$$+ (1.96474) * (ESG^6) + (1.8e\text{-}05) * (EKG^7)$$

$$- (2.67e\text{-}04) * (EKG^6) * (ESG)$$

$$
\begin{aligned}
&- (8.8e\text{-}05) * (EKG^5) * (RESP) * (ESG) \\
&+ (5.97e\text{-}04) * (EKG^5) * (ESG^2) \\
&+ (1.07e\text{-}03) * (EKG^4) * (RESP) * (ESG^2) \\
&+ (1.2e\text{-}04) * (EKG^3) * (RESP^2) * (ESG^2) \\
&+ (2.727e\text{-}03) * (EKG^4) * (ESG^3) \\
&- (1.286e\text{-}03) * (EKG^3) * (RESP) * (ESG^3) \\
&- (9.34e\text{-}04) * (EKG^2) * (RESP^2) * (ESG^3) \\
&- (3.7e\text{-}05) * (EKG) * (RESP^3) * (ESG^3) \\
&+ (2.005e\text{-}03) * (EKG^3) * (ESG^4) \\
&- (7.402e\text{-}03) * (EKG^2) * (RESP) * (ESG^4) \\
&- (9.08e\text{-}04) * (EKG) * (RESP^2) * (ESG^4) \\
&- (5.442e\text{-}03) * (EKG) * (RESP) * (ESG^5) \\
&+ (1.0e\text{-}06) * (EKG^6) * (ESG^2) \\
&- (3.0e\text{-}06) * (EKG^5) * (RESP) * (ESG^2) \\
&- (1.0e\text{-}06) * (EKG^4) * (RESP^2) * (ESG^2) \\
&- (4.0e\text{-}06) * (EKG^4) * (RESP) * (ESG_3) \\
&+ (3.0e\text{-}06) * (EKG^3) * (RESP^2) * (ESG^3) \\
&+ (5.0e\text{-}06) * (EKG^2) * (RESP^2) * (ESG^4) \qquad (14)
\end{aligned}
$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

EKG = Electrocardiograph Data (Beats Per Minute)

RESP = Respiration Data (Breaths Per Volume)

ESG = Electrosplanchnograph Data (Root Mean Square Voltages)

Modeling statistics are shown in Table 30. The ARM software discarded subdelta-delta EEG voltages from the model, since they were not always present in all subjects during motion sickness. Unlike EEG voltages, heart rate, respiration volume and ESG RMS voltages are always present during motion sickness, and generally increased with the increase of motion sickness.

Table 30 *Placebo Motion Sickness* Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE 'LEVEL'	MEAN	8.98485
	SIGMA	4.08802
	MIN	1
	MAX	18
INPUT VARIABLE 'EKG'	MEAN	75.4524
	SIGMA	8.1471
	MIN	58.81
	MAX	95.31
INPUT VARIABLE 'RESP'	MEAN	504.378
	SIGMA	222.949
	MIN	127.78
	MAX	1046.88
INPUT VARIABLE 'ESG'	MEAN	.178595
	SIGMA	.166995
	MIN	.0219
	MAX	.9

Dilantin. Using EKG, respiration, ESG,and EEG data (see Appendix B), the following nonlinear equation was derived relating the level of motion sickness to these physiological parameters.

$$Q1 = .433367 + 1.16339(x-.475982)\,\hat{}\,(1/3) \quad (15)$$

where:

$$x = 63.9702 - (2.69463) * (EKG) + (1.1266e\text{-}02) * (RESP) + (3.5388e\text{-}02) * (EKG^2) - (6.2e\text{-}05) * (EKG) * (RESP) - (3.0e\text{-}06) * (RESP^2) - (1.5e\text{-}04) * (EKG^3) \quad (16)$$

$$Level = (6.33333) + (3.89087) * (Q1) \quad (17)$$

where:

Level = Symptom level
(Control Periods 1-5)
(Asymptomatic)
(MI, MIIB, MIIA, MIII, and Frank Sickness)
(Post Emesis Period 1-5)

EKG = Electrocardiograph Data (Beats Per Minute)

RESP = Respiration Data (Breaths Per Volume)

Modeling statistics are shown in Table 31. The ARM software discarded subdelta-delta EEG voltages and ESG voltages from the model.

Table 31 Dilantin Motion Sickness Modeling Statistics

VARIABLE	STATISTICS	
OUTPUT VARIABLE "LEVEL"	MEAN	6.33333
	SIGMA	3.89087
	MIN	1
	MAX	16
INPUT VARIABLE "EKG"	MEAN	68.2783
	SIGMA	9.27029
	MIN	54.62
	MAX	99.61
INPUT VARIABLE "RESP"	MEAN	569.109
	SIGMA	266.44
	MIN	200
	MAX	1388.89

Prediction Models.

EEG Models. EEG motion sickness trends were developed (see Figure 17) using the EEG RMS voltages of subjects per period (see Table 9). Subject 2 was not included in this graph because of the abnormally high EEG voltages occurring during the baseline period. Figure 17 illustrates that the least susceptible subjects develop subdelta-delta EEG activity early in the experiment and this activity continued through post emesis. Figure 17 also illustrates that the most susceptible subjects developed little or no subdelta-delta EEG activity throughout the experiment; however, subject 1 did develop subdelta-delta EEG activity during post emesis. These data suggest that the subdelta-delta (.05-1HZ range) EEG activity may be a defensive mechanism to cope with unfamiliar motion stimuli. To further support this theory, Figure 18 illustrates that most subjects had a moderate to extremely significant increase in the subdelta-delta EEG activity during the control periods of the dilantin trials. These data suggest that dilantin may increase the subdelta-delta (.05-1HZ range) EEG activity and, as a consequence, provide the human body a possible defense mechanism to tolerate unfamiliar motion stimuli.

Given this theory, two prediction equations were developed using subdelta-delta (.05-1HZ range) EEG activity as a variable. The first equation used RMS voltages, collected at the MIIB period, to predict the duration time of a subject. The second equation used MIIB RMS voltages to predict the susceptibility level of a subject. For the second equation, subjects were identified as highly susceptible (1), moderately susceptible (2), or least susceptible (3).

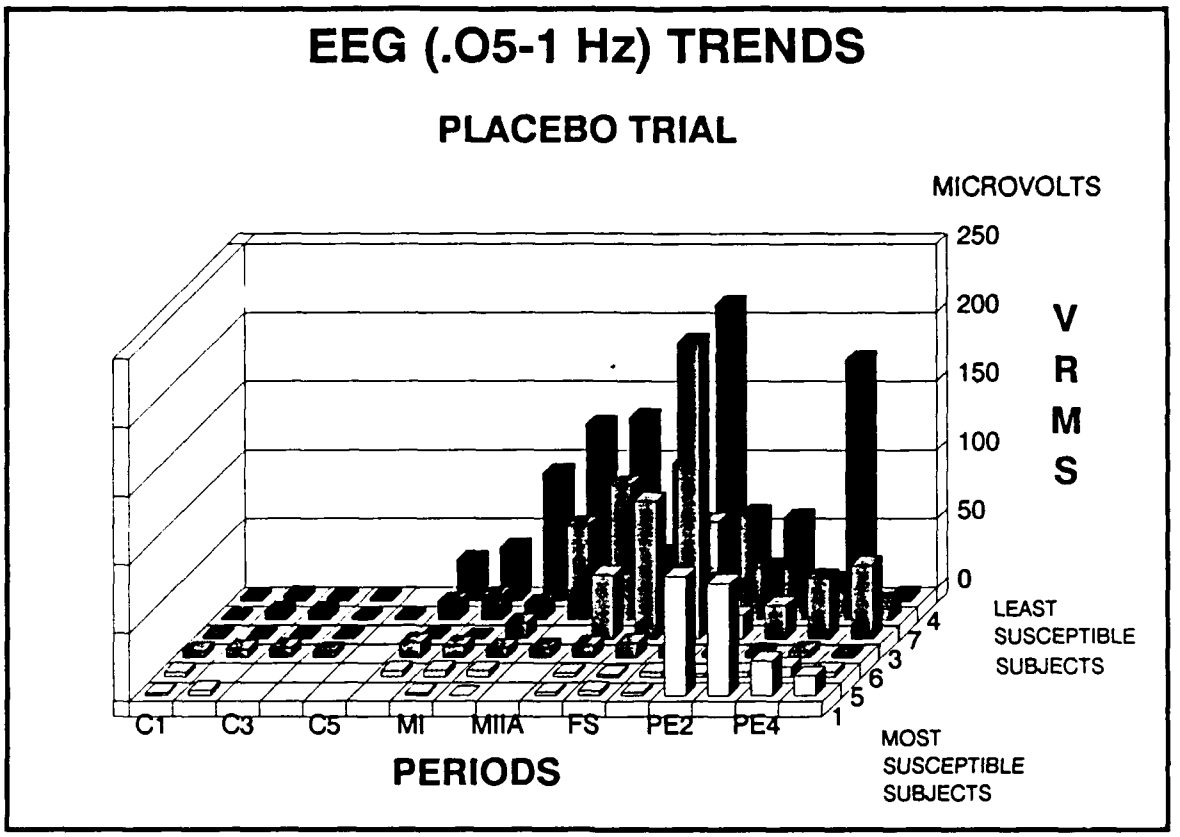

Figure 17 EEG Trends of Subjects During Placebo Trial

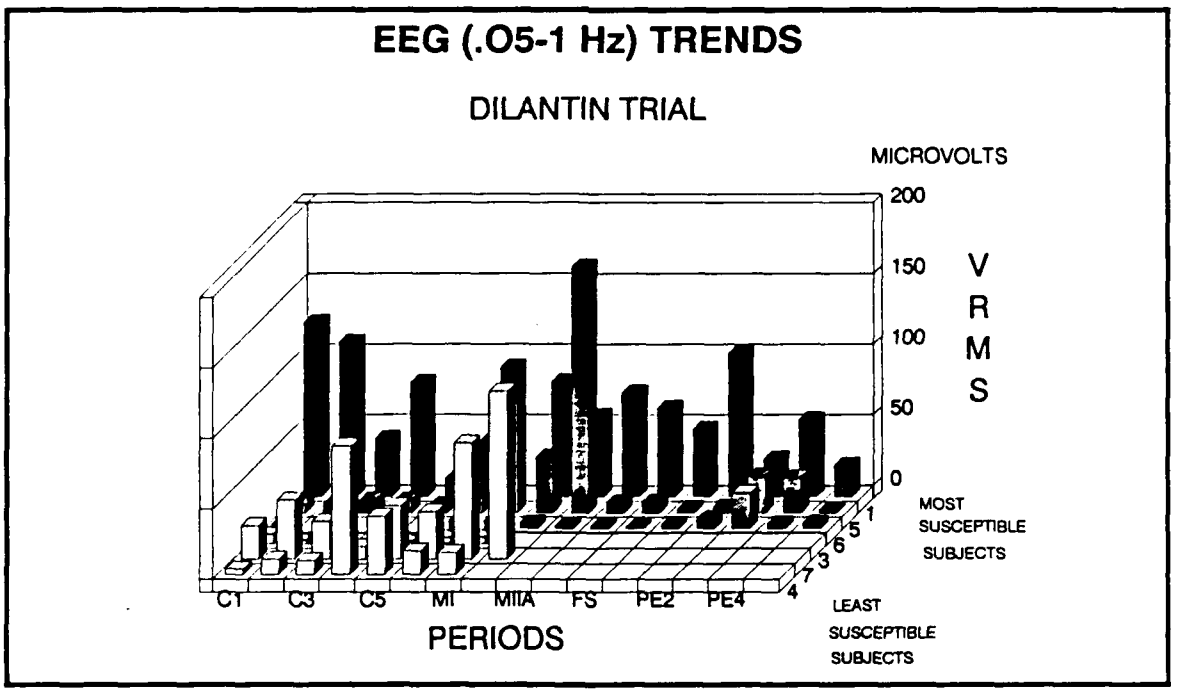

Figure 18 EEG Trends of Subjects During Dilantin Trial

Duration Prediction. Using EEG data and duration times (see Table 32) the following prediction equation was derived relating the duration times to EEG voltages.

$$\text{Time} = (6.3663) + (5.3324\text{e-}02) * (\text{EEG}) \quad (18)$$

where:

Time = Duration Time (Minutes)

EEG = MIIB Root Mean Square Voltages (Microvolts)

The EEG data from Table 32 were used to verify the equation. The results (see Table 33) suggest that ARM did not have sufficient input to train itself properly and, as a consequence, unable to develop an accurate model.

Table 32 EEG Test Data

SUBJECT	TIME	EEG
1	2	18.02
5	7	22.08
6	8	34.5
3	13	46.3
7	14	61.5
4	26	414

Table 33 Prediction Results

SUBJECT	TIME	EEG
1	7.3272	18.02
5	7.5437	22.08
6	8.20588	34.5
3	8.83552	46.3
7	9.64573	61.5
4	26	414

Susceptibility Prediction. Using EEG data and susceptibility levels (see Table 34) the following prediction equation was derived relating susceptibility levels to EEG voltages.

$$Level = (1.59427) + (4.082e\text{-}03) * (EEG) \quad (19)$$

where:

Level = Susceptibility Level (1, 2, or 3)

EEG = MIIB Root Mean Square Voltages (Microvolts)

The EEG data from Table 34 were used to verify the equation. The results (see Table 35) suggest that ARM was quite successful in predicting susceptibility, but further input should improve the equation.

Table 34 EEG Test Data

SUBJECT	SUSCEPTIBILITY	EEG
1	1	18.02
5	2	22.08
6	2	34.5
3	2	46.3
7	2	61.5
4	3	414

Table 35 Prediction Results

SUBJECT	SUSCEPTIBILITY	EEG
1	1.66783	18.02
5	1.6844	22.08
6	1.73509	34.5
3	1.78326	46.3
7	1.8453	61.5
4	3	414

Dilantin Blood Levels. A prediction model using dilantin blood serum levels was used because the serum level data suggested that the therapeutic motion sickness range was between 12.3 and 12.4 micrograms per milliliter.

$$\text{Time} = -1765.07 + (300.333) * (\text{DBL}) - (12.2646)\,(\text{DBL}^2) \qquad (20)$$

where:

Time = Duration Time (Minutes)

DBL = Dilantin Blood Levels (Micrograms/Milliliter)

The dilantin blood level data from Table 36 were used to verify the equation. The results (see Table 37) suggest that ARM did not have sufficient input, especially DBLs less than 12.0, to train itself properly. Consequently, it was unable to develop a more accurate model.

Table 36 Dilantin Blood Level Test Data

SUBJECT	TIME	DILANTIN BLOOD LEVELS
2	42	12.0
3	90	12.3
4	97	12.3
6	80	12.4
7	54	13.0
5	28	14.0
1	8	14.7

Table 37 Prediction Results

SUBJECT	TIME	DILANTIN BLOOD LEVELS
2	72.8306	12.0
3	73.5218	12.3
4	73.5218	12.3
6	73.2616	12.4
7	66.5494	13.0
5	35.739	14.0
1	6	14.7

Regression Analysis

According to Mendenhall, McClave, and Ramey, "If we can establish that a relationship exists between variables, we may then exploit this relationship to accomplish another inferential objective: prediction" (30:368). Linear regression was used predict duration time and susceptibility levels.

EEG.

According to the data, there was a strong linear relationship between MIIB EEG RMS voltages and duration time ($r = .8960139508$, $n = 6$, $DF = 4$, alpha = .01, $r_{critical} = .882$). Using EEG data and duration times (see Table 38) the following prediction equation was derived relating the duration times to EEG voltages.

$$\text{Time} = (6.917434) + (.047779) * (\text{EEG}) \qquad (21)$$

where:

Time = Duration Time (Minutes)

EEG = MIIB Root Mean Square Voltages (Microvolts)

Std ERR of Y Est = 4.101734

r2 = .802841

Std Err of Coef. = .011839

A scatter plot and linear model (see Figure 19) were generated using EEG data from Table 38. The EEG data from Table 38 were also used to verify the equation. The results (see Table 39) suggest that more data is required to enhance the equation. Additionally, these results were very similar to the results produced by the ARM software.

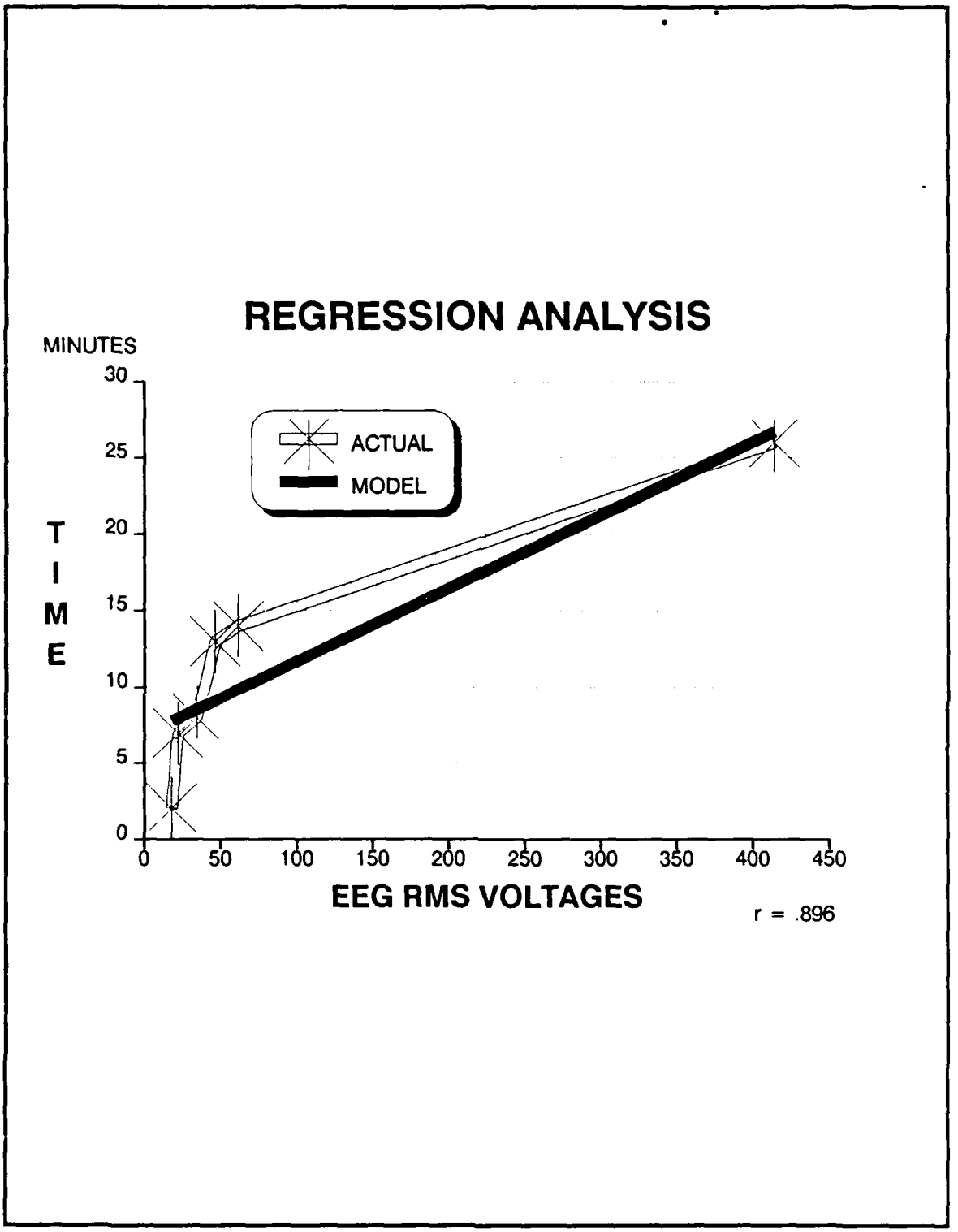

Figure 19 EEG vs Time Scatter Plot and Linear Model

Table 38 EEG Test Data

SUBJECT	TIME	EEG
1	2	18.02
5	7	22.08
6	8	34.5
3	13	46.3
7	14	61.5
4	26	414

Table 39 Prediction Results

SUBJECT	TIME	EEG
1	7.778412	18.02
5	7.972394	22.08
6	8.56581	34.5
3	9.129802	46.3
7	9.855843	61.5
4	26.69794	414

Dilantin Blood Level. According to the data, there was an inverse linear relationship between dilantin blood levels and duration time. ($r = -.80354$, $n = 7$, $DF = 5$, alpha = .05, $r_{critical} = -.669$). Using dilantin blood level data and duration times (see Table 40) the following prediction equation was derived relating the duration times to dilantin blood levels.

$$Time = (406.0809) - (26.9853) * (DBL) \quad (22)$$

where:

Time = Duration Time (Minutes)

DBL = Dilantin Blood Level (Microgram/Milliliter)

Std ERR of Y Est = 22.29059

r2 = .645685

Std Err of Coef. = 8.939767

The dilantin blood level data from Table 40 were used to verify the equation. The results (see Table 41) suggest that more data is required to enhance the equation. Additionally, these results were similar to the results produced by ARM software. Both modeling techniques, ARM and linear regression, predicted an extremely incorrect duration time for subject 2. This error suggests that the model is nonlinear (Table 41 and Figure 20). As further evidence, at least three subjects were eliminated from this research because their dilantin levels were less than 12.0 micrograms/milliliter.

Their levels ranged between 9.0 and 11.0 and their duration times ranged between 6 minutes and 16 minutes. The model may actually be bell shape with a maximum at

12.3-12.4. If this is the case, then a quadratic regression model should be used to predict duration time using dilantin blood levels (11:515).

Table 40 Dilantin Blood Level Test Data

SUBJECT	TIME	DILANTIN BLOOD LEVELS
2	42	12.0
3	90	12.3
4	97	12.3
6	80	12.4
7	54	13.0
5	26	14.0
1	6	14.7

Table 41 Prediction Results

SUBJECT	TIME	DILANTIN BLOOD LEVELS
2	82.25735	12.0
3	74.16176	12.3
4	74.16176	12.3
6	71.46324	12.4
7	55.27206	13.0
5	28.28676	14.0
1	9.397059	14.7

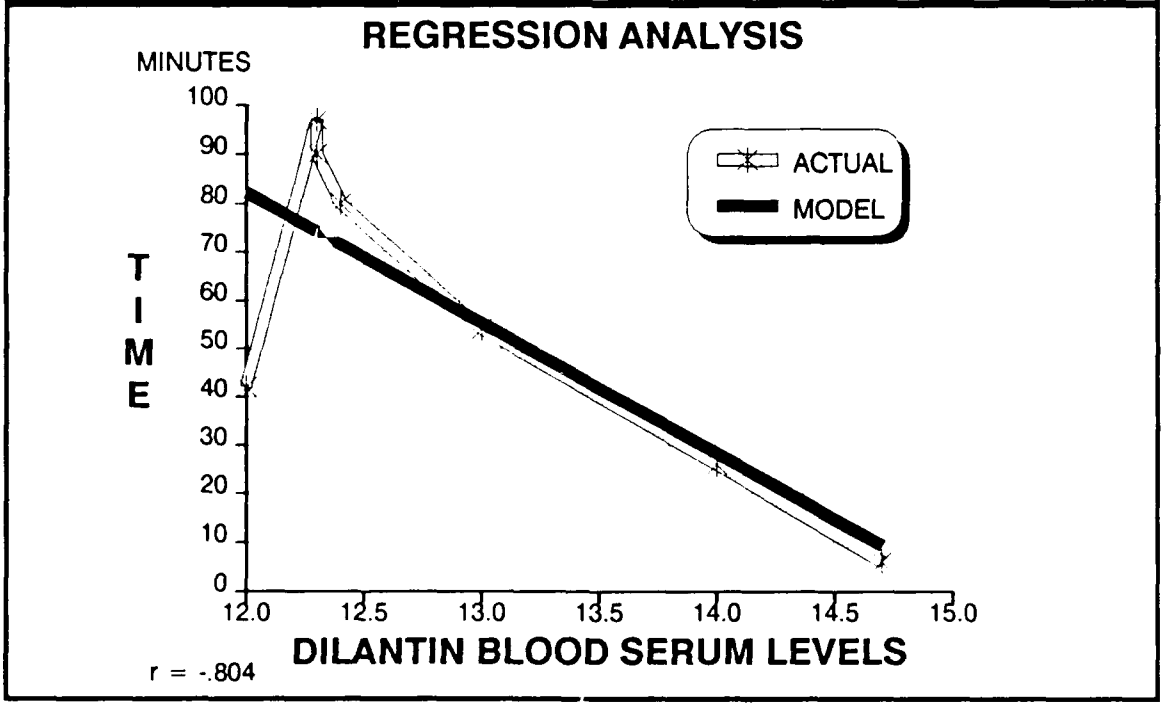

Figure 20 DBL vs Time Scatter Plot and Linear Model

Space Motion Sickness Prediction

EEG may be the significant physiological parameter needed to develop adequate SMS prediction models. Possibly, the EEG models or methodology developed in this research could be used to predict space motion sickness preflight. The first step would be to use astronauts with flight experience as subjects in a motion stimulus simulation and to collect EEG data on them. The second step would be to try to correlate data with the population that had SMS and the population that did not. Finally, if a correlation exists then try to develop SMS prediction models using either a neural network or linear regression.

VI. Discussion

Subjects treated with dilantin were found to have a greater tolerance to motion sickness than when they were treated with a placebo. Also, dilantin did not affect the physical performance and cognitive skills of the subjects. This research also added new light on the subdelta-delta EEG activity. The research pertaining to this document led to a new discovery and a new theory in motion sickness. Based on a thorough investigation of subdelta-delta EEG data, the new theory suggests that the *subdelta-delta EEG activity is a defense mechanism to cope with unfamiliar motion stimuli and that dilantin may enhance this activity*. This research also used a neural network model and linear regression model to predict duration time of motion sickness in individuals and susceptibility motion sickness levels of individuals. The combination of the EEG parameter and these models may lay the ground work in achieving an adequate space motion sickness prediction model.

Physiological Parameters

Heart Rate. Heart rates tended to increase with the increase of motion sickness, but heart rates also leveled off or dropped slightly during certain periods of motion sickness before reaching a peak at or near frank sickness. This behavior suggests that subjects were adapting to motion sickness.

Respiration Volume. Respiration intake tended to increase with the increase of motion sickness. Very little motion sickness adapting was observed in this parameter.

ESG Voltages. In general, ESG voltages increased with the increase of motion sickness but reached a maximum at MIIA instead of at frank sickness.

EEG Voltages. The RMS subdelta-delta EEG activity peaked during the mid to late periods of motion sickness (MIIA - MIII).

Recommendation

1. Future research should focus more attention on the relationship between subdelta-delta EEG activity and motion sickness. The research should increase the number of EEG channels from five to sixteen and purchase a computerized brain mapping system. The combination of these two changes should allow researchers to locate the origin of the subdelta-delta EEG activity and to track its spread.
2. Acquire a new motion sickness chair that has at least 50 slip rings.
3. Investigate the efficacy of other anticonvulsants in treating motion sickness.
4. Investigate the efficacy of dilantin in microgravity sickness and space motion sickness.
5. Submit Military Man in Space research proposal (see appendix C) to the Air Force MMIS board.
6. Incorporate CO_2 collection in next year's trials. Initial data collected this year supports the claim that subject hyperventilate during motion sickness.
7. Use the subdelta-delta EEG parameter as a feeback parameter in Autogenic Feedback training.
8. Investigate the use of spectral analysis to study heart rate variability. An example of spectral analysis of heart rate variability is shown in Figure 21. Figure 21 illustrates the power spectrum of subject 6's heart rate variability during the later

• stages of motion sickness (MIIA - Frank Sickness). Most of the power resided in the .02 region which may be correlated with the peripheral (finger) photo plelethysmograph data.

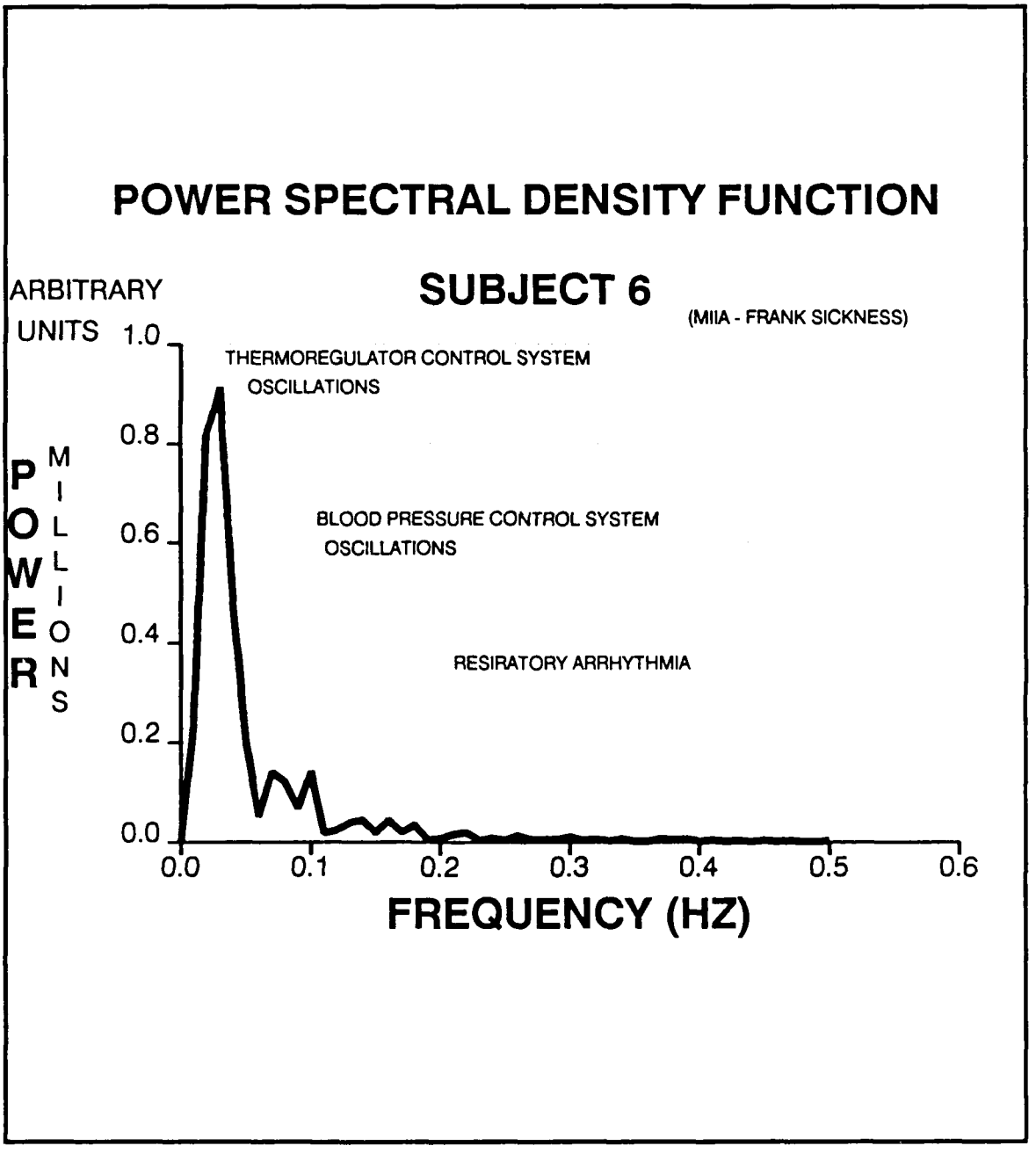

Figure 21 Power Spectrum of Heart Rate Variability

Conclusion

The United States space program cannot afford, economically, politically, or psychologically, to continue to send astronauts into space and have them spend two to three days adapting to the microgravity environment. Much time and money is lost when astronauts cannot perform operational objectives because they are suffering from space motion sickness. In addition, NASA leaders can ill afford to jeopardize the lives of the astronauts because of space motion sickness. Because the American people have a hard time accepting space accidents or fatalities, such as the Challenger accident, a space motion sickness related accident or death could temporarily set back the space program until a cure for space sickness was found.

Unfortunately, for the future, astronauts will have to rely on the traditional antimotion sickness drugs such as scopolamine and dexedrine (23:36-2).

Meanwhile, motion sickness research will continue at AFIT and NASA. Both AFIT and NASA researchers have studied the physiological responses to motion sickness and are currently pursuing treatments to space motion sickness. The AFIT research team is studying the effect of anticonvulsants on motion sickness. At the same time, the NASA research teams are investigating the use of both therapeutic agents, autogenic feedback training and preadaptation training in controlling space motion sickness (8:19).

NASA researchers have not been successful in predicting space motion sickness (17). One reason may be that the NASA research teams are not using the key physiological parameter(s) in their prediction equations. New parameters should be investigated; one possible candidate is the low frequency (subdelta-delta) brain signals discovered by the AFIT research team.

With the projected increase in manned spaceflight it is vital to develop a method for screening crews for space motion susceptibility and/or develop a cure for space motion sickness. The projected cost of space motion sickness over the next fifty flights could be as much as **$500 million.**

Appendix A

Subjects' Malaise Levels

DATE : 1 Jul 88

SUBJECT : 1	TRIAL : 1	TREATMENT : PLACEBO
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		74
CONTROL 2		104
CONTROL 3		
CONTROL 4		
CONTROL 5		
ASYMPTOMATIC	17:05:49	190
MI	17:06:09	195
MIIB	17:06:33	207
MIIA	17:07:04	223
MIII	17:07:16	229
FRANK SICKNESS	17:07:46	244
POST EMESIS +1		288
POST EMESIS +2		318
POST EMESIS +3		348
POST EMESIS +4		378
POST EMESIS +5		408

DATE : 7 Jul 88

SUBJECT : 2 TRIAL : 2 TREATMENT : PLACEBO

PERIOD	TIME	BETA RECORDER ADDRESS
CONTROL 1		138
CONTROL 2		168
CONTROL 3		198
CONTROL 4		228
CONTROL 5		258
ASYMPTOMATIC	17:00:56	384
MI	17:02:31	432
MIIB	17:04:16	485
MIIA	17:04:24	489
MIII	17:04:55	505
FRANK SICKNESS	17:05:09	512
POST EMESIS +1		548
POST EMESIS +2		578
POST EMESIS +3		608
POST EMESIS +4		638
POST EMESIS +5		668

DATE : 14 Jul 88

SUBJECT : 3	TRIAL : 2	TREATMENT : PLACEBO
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		178
CONTROL 2		208
CONTROL 3		238
CONTROL 4		268
CONTROL 5		
ASYMPTOMATIC	16:25:05	384
MI	16:27:26	448
MIIB	16:30:16	533
MIIA	16:31:17	560
MIII	16:34:33	654
FRANK SICKNESS	16:38:09	757
POST EMESIS +1		797
POST EMESIS +2		827
POST EMESIS +3		857
POST EMESIS +4		887
POST EMESIS +5		917

DATE : 14 Jul 88

SUBJECT : 4	TRIAL : 2	TREATMENT : PLACEBO
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		85
CONTROL 2		115
CONTROL 3		145
CONTROL 4		175
CONTROL 5		205
ASYMPTOMATIC	16:46:24	635
MI	16:49:50	738
MIIB	16:50:43	764
MIIA	16:52:49	827
MIII	17:01:41	1093
FRANK SICKNESS	17:12:07	1370
POST EMESIS +1		548
POST EMESIS +2		578
POST EMESIS +3		608
POST EMESIS +4		638
POST EMESIS +5		668

DATE : 4 Aug 88

SUBJECT : 5 TRIAL : 1 TREATMENT : PLACEBO

PERIOD	TIME	BETA RECORDER ADDRESS
CONTROL 1		52
CONTROL 2		82
CONTROL 3		112
CONTROL 4		142
CONTROL 5		172
ASYMPTOMATIC	15:53:16	193
MI	15:54:06	218
MIIB	15:55:07	248
MIIA	15:57:13	305
MIII	15:59:03	360
FRANK SICKNESS	15:59:46	381
POST EMESIS +1		418
POST EMESIS +2		448
POST EMESIS +3		478
POST EMESIS +4		508
POST EMESIS +5		538

DATE : 8 Sep 88

SUBJECT : 6	TRIAL : 2	TREATMENT : PLACEBO
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		534
CONTROL 2		564
CONTROL 3		594
CONTROL 4		624
CONTROL 5		654
ASYMPTOMATIC	16:47:33	731
MI	16:50:29	817
MIIB	16:51:29	847
MIIA	16:52:15	868
MIII	16:53:13	896
FRANK SICKNESS	16:55:09	947
POST EMESIS +1		999
POST EMESIS +2		1029
POST EMESIS +3		1059
POST EMESIS +4		1089
POST EMESIS +5		1119

DATE : Sep 88

SUBJECT : 7	TRIAL : 1	TREATMENT : PLACEBO
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		450
CONTROL 2		480
CONTROL 3		510
CONTROL 4		540
CONTROL 5		570
ASYMPTOMATIC	16:00:27	639
MI	16:01:06	659
MIIB	16:03:38	735
MIIA	16:05:43	794
MIII	16:08:56	887
FRANK SICKNESS	16:13:36	1018
POST EMESIS +1		1078
POST EMESIS +2		1108
POST EMESIS +3		1138
POST EMESIS +4		1168
POST EMESIS +5		1198

DATE : 8 Jul 88

SUBJECT : 1	TRIAL : 2	TREATMENT : DILANTIN
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		275
CONTROL 2		305
CONTROL 3		335
CONTROL 4		365
CONTROL 5		395
ASYMPTOMATIC	16:43:53	458
MI	16:46:11	527
MIIB	16:47:09	568
MIIA	16:47:34	568
MIII	16:48:21	588
FRANK SICKNESS	16:48:44	604
POST EMESIS +1		613
POST EMESIS +2		643
POST EMESIS +3		673
POST EMESIS +4		703
POST EMESIS +5		733

DATE : 13 Jul 88

SUBJECT : 2	TRIAL : 2	TREATMENT : DILANTIN
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		88
CONTROL 2		118
CONTROL 3		148
CONTROL 4		178
CONTROL 5		208
ASYMPTOMATIC	16:11:07	318
MI	16:31:24	893
MIIB	16:33:06	945
MIIA	16:43:06	1232
MIII	16:52:18	1491
FRANK SICKNESS	16:52:30	1497
POST EMESIS +1		
POST EMESIS +2		
POST EMESIS +3		
POST EMESIS +4		
POST EMESIS +5		

DATE : 22 Jul 88

SUBJECT : 3	TRIAL : 2	TREATMENT : DILANTIN
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		126
CONTROL 2		156
CONTROL 3		186
CONTROL 4		216
CONTROL 5		246
ASYMPTOMATIC	16:52:54	438
MI	18:11:33	1133
MIIB	18:18:46	1385
MIIA		
MIII		
FRANK SICKNESS		
POST EMESIS +1		
POST EMESIS +2		
POST EMESIS +3		
POST EMESIS +4		
POST EMESIS +5		

DATE : 15 Jul 88

SUBJECT : 4 TRIAL : 1 TREATMENT : DILANTIN

PERIOD	TIME	BETA RECORDER ADDRESS
CONTROL 1		170
CONTROL 2		200
CONTROL 3		230
CONTROL 4		260
CONTROL 5		290
ASYMPTOMATIC	16:13:08	329
MI	17:19:30	725
MIIB		
MIIA		
MIII		
FRANK SICKNESS		
POST EMESIS +1		
POST EMESIS +2		
POST EMESIS +3		
POST EMESIS +4		
POST EMESIS +5		

DATE : 12 Aug 88

SUBJECT : 5	TRIAL : 2	TREATMENT : DILANTIN
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		195
CONTROL 2		225
CONTROL 3		255
CONTROL 4		285
CONTROL 5		315
ASYMPTOMATIC	15:18:25	406
MI	15:35:43	905
MIIB	15:36:49	932
MIIA	15:39:43	1018
MIII	15:42:25	1090
FRANK SICKNESS	15:43:53	1145
POST EMESIS +1		1155
POST EMESIS +2		1185
POST EMESIS +3		1215
POST EMESIS +4		1245
POST EMESIS +5		1275

DATE : 30 Aug 88

SUBJECT : 6 TRIAL : 1 TREATMENT : DILANTIN

PERIOD	TIME	BETA RECORDER ADDRESS
CONTROL 1		211
CONTROL 2		241
CONTROL 3		271
CONTROL 4		301
CONTROL 5		331
ASYMPTOMATIC	17:20:11	423
MI		
MIIB		
MIIA		
MIII		
FRANK SICKNESS		
POST EMESIS +1		
POST EMESIS +2		
POST EMESIS +3		
POST EMESIS +4		
POST EMESIS +5		

DATE : Aug 88

SUBJECT : 7	TRIAL : 2	TREATMENT : DILANTIN
PERIOD	**TIME**	**BETA RECORDER ADDRESS**
CONTROL 1		38
CONTROL 2		
CONTROL 3		
CONTROL 4		
CONTROL 5		
ASYMPTOMATIC	14:20:05	96
MI	14:25:13	243
MIIB	15:13:28	111
MIIA	15:13:40	116
MIII	15:13:52	122
FRANK SICKNESS	15:13:59	125
POST EMESIS +1		130
POST EMESIS +2		160
POST EMESIS +3		190
POST EMESIS +4		220
POST EMESIS +5		250

Appendix B

1988 ARM Motion Sickness Data

PLACEBO TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
1	7	74.53	575	.134	2.17	9.98
2	8	78.65	738.88	.124	4.06	18.02
3	10	80.2	905	.138	2.36	12.83
4	11	79.91	1046.875	.154	3.74	17.59
5	12	83.76	639.28	.246	2.77	14.00
6	13	86.03	526.56	.485	87.4	310.7
7	1	73.57	285.58	.0342	56.9	171.9
8	3	71.35	297.37	.0633	38.3	149.22
9	4	69.13	439.58	.133	70	157.7
10	5	77.07	307.29	.158	104	383
11	6	95.31	490.63	.0935	70.5	303
12	7	84.56	354.29	.0934	68.5	304
13	8	77.9	500	.228	2.54	10.69
14	9	82.87	487.5	.136	15.6	49.7
15	10	94.04	787.5	.223	128	341
16	11	81.12	830.56	.688	13.3	54.9
17	12	81.55	652	.705	54.3	198.2
18	7	73.68	542.95	.273	1.17	5.23
19	8	71.48	648.53	.165	11.9	46.3
20	10	69.24	718.75	.227	47	280
21	11	93.79	790	.356	25	84.8
22	12	85.15	610	.317	12.4	64.8
23	13	81.16	680	.254	17.7	92.4
24	14	77.95	535.71	.15	44.9	202.7
25	15	70.42	408.82	.295	54.2	220

1 = C1
2 = C2
3 = C3
4 = C4
5 = C5

6 = ASYMPTOMATIC
7 = MI
8 = MIIB
9 = MIIA
10 = MIII
11 = FRANK SICKNESS

12 = PE1
13 = PE2
14 = PE3
15 = PE4
16 = PE5

PLACEBO TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
26	16	72.79	301.56	.2950	54.2	220.0
27	1	69.94	411.90	.0765	2.92	13.33
28	2	68.44	464.29	.0347	4.30	27.3
29	3	74.73	414.28	.0932	2.80	15.68
30	4	66.42	443.48	.0551	2.68	17.58
31	5	71.98	475.00	.0853	4.14	26.7
32	6	71.62	658.87	.0917	30.2	279.1
33	7	72.46	679.41	.3450	39.2	160.6
34	8	70.57	684.46	.2460	93.7	414.0
35	11	83.69	850.00	.9000	101	374.0
36	12	69.74	818.75	.3750	216	789.0
37	13	67.26	653.33	.0347	25.5	86.0
38	14	67.64	559.00	.3480	15.9	65.6
39	6	84.93	428.24	.0377	4.18	20.71
40	7	77.20	465.00	.0219	4.58	20.67
41	8	82.43	486.00	.0715	4.52	22.08
42	10	77.38	662.50	.2190	2.52	13.07
43	11	87.61	691.67	.0829	1.75	9.50
44	12	67.32	583.33	.1720	3.65	21.19
45	13	68.35	742.31	.1440	2.45	13.54
46	14	66.15	786.36	.1150	3.50	17.10
47	15	66.44	800.00	.2710	7.46	32.81
48	16	59.81	610.42	.1070	3.88	18.51
49	1	65.09	165.00	.0359	5.07	27.99
50	2	65.95	165.00	.0314	6.42	26.80
51	3	64.95	155.26	.0349	7.33	31.80
52	4	68.17	161.25	.0323	4.85	21.59
53	6	68.12	206.70	.0365	11.7	58.70
54	7	82.99	216.25	.0346	9.43	61.30
55	8	79.86	236.53	.2480	7.10	34.50
56	9	86.04	304.42	.2240	7.50	38.70

PLACEBO TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
57	10	84.14	277.14	.1010	8.99	59.4
58	11	89.80	245.83	.2210	11.10	49.4
59	12	79.86	247.41	.1150	8.07	34.5
60	13	70.21	182.81	.0868	4.38	19.49
61	14	66.42	127.78	.0408	3.87	22.80
62	6	70.85	447.06	.0437	13.80	68.70
63	7	73.42	626.04	.0940	17.50	120.00
64	8	76.49	721.74	.2440	12.30	61.50

DILANTIN TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
1	1	67.35	200.00	.0370	27.8	113.60
2	2	69.74	203.57	.0464	6.97	37.60
3	6	99.61	554.55	.0620	40.0	160.60
4	7	76.57	623.68	.0370	45.9	197.40
5	8	86.80	660.00	.3610	46.0	168.00
6	9	74.03	683.82	.2490	244.00	776.00
7	10	81.88	700.00	.2480	329.00	973.00
8	11	83.23	910.00	.1100	352.00	973.00
9	1	75.63	471.74	.0700	24.1	121.20
19	2	65.56	530.43	.0539	42.2	201.30
11	3	71.73	584.21	.0512	27.0	98.80
12	4	76.00	478.95	.0419	8.9	39.50
13	5	76.75	641.67	.0423	38.3	151.30
14	6	72.21	672.73	.1170	33.9	159.90
15	7	67.78	660.00	.1170	82.5	297.00
16	8	72.74	785.19	.0368	119.00	378.00
17	1	65.58	237.50	.1770	4.26	221.84
18	2	67.17	309.64	.0345	11.10	51.80
19	3	69.07	372.06	.5190	10.20	61.30
20	4	66.84	364.71	.1540	91.40	413.00
21	5	79.83	307.94	.0328	41.70	150.40
22	6	71.78	406.25	.0306	17.20	76.30
23	1	70.04	515.38	.0492	5.95	34.00
24	2	65.89	481.82	.0716	6.78	35.40
25	3	56.42	453.85	.0496	9.23	41.10
26	4	64.08	550.00	.041	9.17	45.90
27	5	63.92	536.36	.0501	6.00	33.70
28	6	69.41	557.14	.0428	6.05	30.20
29	7	65.43	764.28	.2190	103.00	492.00
30	8	65.71	721.67	.108	39.50	189.60
31	9	65.77	906.52	.4570	174.00	632.00
32						

DILANTIN TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
33	10	67.52	1032.50	.0878	7.73	54.4
34	11	61.08	1350.00	.0443	8.10	40.40
35	12	55.47	1288.89	.0418	2.89	16.40
36	13	55.95	968.75	.0465	4.33	20.67
37	14	59.66	745.45	.0425	26.40	99.10
38	15	56.94	638.88	.0700	24.90	112.90
39	16	57.08	725.00	.0364	2.28	13.07
40	1	60.59	236.11	.0351	6.72	36.10
41	2	54.62	205.56	.0377	2.52	14.97
42	3	55.09	202.5	.0400	1.65	9.26
43	5	56.34	275.00	.0387	1.86	12.83
44	6	58.22	250.00	.0494	4.85	33.50
45	6	77.75	408.33	.1170	4.73	21.82
46	7	78.58	461.36	.0547	5.60	22.30
47	8	68.45	450.00	.3150	4.09	18.79
48	9	72.83	533.23	.3660	1.58	7.13
49	10	57.65	600.00	.3990	1.57	7.61

DILANTIN TRIAL

Observation Number	Symptom Level	EKG (BPM)	RESP (VPP)	ESG (VRMS)	EEG (VRMS)	EEG (PEAK)
33	10	67.52	1032.50	.0878	7.73	54.4
34	11	61.08	1350.00	.0443	8.10	40.40
35	12	55.47	1288.89	.0418	2.89	16.40
36	13	55.95	968.75	.0465	4.33	20.67
37	14	59.66	745.45	.0425	26.40	99.10
38	15	56.94	638.88	.0700	24.90	112.90
39	16	57.08	725.00	.0364	2.28	13.07
40	1	60.59	236.11	.0351	6.72	36.10
41	2	54.62	205.56	.0377	2.52	14.97
42	3	55.09	202.5	.0400	1.65	9.26
43	5	56.34	275.00	.0387	1.86	12.83
44	6	58.22	250.00	.0494	4.85	33.50
45	6	77.75	408.33	.1170	4.73	21.82
46	7	78.58	461.36	.0547	5.60	22.30
47	8	68.45	450.00	.3150	4.09	18.79
48	9	72.83	533.23	.3660	1.58	7.13
49	10	57.65	600.00	.3990	1.57	7.61

Appendix C

Military Man in Space Proposal

MILITARY MAN IN SPACE RESEARCH PROPOSAL

1. TITLE: Evaluation of the Therapeutic Efficacy of *Anticonvulsants in Space Motion Sickness (OPTION 1).

2. Principal Investigators:

William Chelen, M.D. ;
(513) 255-5276; AFIT/ENG

Capt Rogelio Morales, Jr., B.S. ;
(513) 255-5276; AFIT/ENG

Associate Investigators:

Colonel Charles Hatsell, M.D. ;
(513) 255-4649; USAF/MC

Matthew Kabrisky, Ph.D. ;
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Capt Russel Smith, B.S. ;
(513) 255-5276; AFIT/ENG

Capt Edward Fix, M.S. ;
(513) 255-7590; AAMRL/HED

3. DATE: 28 Sep 1988

* Anticonvulsant options: Dilantin (First choice based previous ground based efficacity), Dextromethorphan\Dilantin, Carbamazepine, Dextromethorphan\Carbamazepine

EVALUATION OF THE THERAPEUTIC EFFICACY OF ANTICONVULSANTS IN SPACE MOTION SICKNESS

OPTION 1: FULLY INSTRUMENTED EXPERIMENT

I. Concept

A. Objectives. Investigate the etiology and therapy of space motion sickness on 15 subjects over several space shuttle missions.

1. Explore the etiology of space motion sickness and its relationship to psychomotor/partial seizures.

2. Investigate the use of anticonvulsants in treating and preventing space motion sickness.

3. Investigate the use of new methods, including pattern recognition techniques, in predicting space motion sickness preflight.

4. Identify new parameters to be used in biofeedback techniques.

5. Provide serum samples of alternative biochemical analysis for other investigators of space motion sickness.

B. Experiment Description

1. Subjects. Payload Specialists\Mission Specialists

2. Experimental Technique. Double-blind, Single-blind,or Treat all - To be determined as a function of the mission subjects' availability constraints.

3. Medication.

a. Anticonvulsants

b. Placebo - TBD

4. Apparatus

a. Silver-silver chloride electrodes

a. Silver-silver chloride electrodes

b. Platinum subdermal electrodes or gold surface electrodes

c. Respiration tranducers and cabling

d. Three portable data recorders

e. Miniature centrifuge

f. Miniature freezer

g. Hypodermic blood drawing supplies

5. Measurements

a. One Electrocardiogram (EKG) channel (Lead II)

b. Sixteen Electroencephalographic (EEG) channels

c. Two respiration channles

d. Two ENG channels

e. Two ESG (EGG) channels

6. Procedure.

a. Preflight

(1) Ground based motion sickness evaluations (Coriolis induced motion sickness susceptibility trials).

(2) Anticonvulsant therapeutic evaluation tests (Coriolis induced motion sickness trials)

(a) Tolerance to medication

(b) Absorption rate of medication/serum level determination

(c) Time course of therapeutic level measurement

(d) Computerized cognition and performance testing

(e) Crew procedural training

b. Inflight Requirements

(a) Take orally prelaunch and subsequent oral doses inflight

(b) Take orally after symptoms appear and subsequent doses as tolerated.

(c) Take by injection after symptoms appear and subsequent doses as tolerated (A physician should be onboard)

(2) Instrument the subjects on a noninterference basis

(3) Blood collection/processing

(a) Blood sample centrifugation

(b) Blood serum freezing

(4) Monitor physiological parameters on mission days 0 through 3.

(5) Record SMS symptoms in a log book

(6) During post-sleep period

(a) Replace electrodes

(b) Replace data tape

(c) Replace new batteries in the data recorders

c. Post Flight Requirements

(1) Debriefing session

(2) Serum level determination of frozen samples

II. Justification

A. Military Relevance. Space motion sickness is a very expensive disease that affects both NASA and DOD Space Shuttle crew members. Planned crew activites are disrupted when space motion sickness threatens crew safety, crew operations and crew comfort. Consequently, the loss of productive time has cost the space program approximately $10 million per Space Shuttle flight.

1. Crew Safety. Space motion sickness is a potential mortal danger to susceptible astronauts. Astronauts suffering from space motion sickness are prevented from performing extra vehicular activities. A degradation in their health, such as headaches, malaise, lethargy, nausea, and/or vomiting, increases the danger of an already dangerous situation.

2. **Operations.** This year, NASA personnel reported that 67 percent of the crew members of the first twenty-four Space Shuttle flights reported space motion sickness symptoms. Almost half of the reported 67 percent of space motion sickness cases impacted operations. Space motion sickness has the potential of jeapordizing the success of DOD Inertial Upper Stage missions, free flyer missions (e.g., Air Force Program 888) and sortie missions (e.g., Air Force Program 675 and STARLAB).

3. **Comfort.** The space motion sickness symptoms reported by astronauts are anorexia, headache, malaise, lethargy, general stomach discomfort and vomiting. In severe cases, these symptoms may persist beyond 72 hours. Unfortunately, anti-motion sickness medication has had little success in preventing space motion sickness. Consequently, non-cured crew members must attempt to continue normal operations while suffering from space motion sickness.

B. **Crew Involvement.** Payload Specialist(s) would participate as subjects in the experiment. If agreed, mission specialists could be treated with the medication as well.

C. **Comparison of Alternatives.** The intent is to prevent space motion sickness; therefore, the experiment must be conducted in space.

D. **Cost Estimate and Funding Potential Experiment Maturity.** TBD

E. **Readiness for Flight.** This experiment could be ready by Jan 1990.

MILITARY MAN IN SPACE RESEARCH PROPOSAL

1. TITLE: Evaluation of the Therapeutic Efficacy of *Anticonvulsants in Space Motion Sickness (OPTION 2).

2. Principal Investigators:

William Chelen, M.D.;
(513) 255-5276; AFIT/ENG

Capt Rogelio Morales, Jr., B.S.;
(513) 255-5276; AFIT/ENG

Associate Investigators:

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Capt Mark Scott, B.S.;
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Capt Russel Smith, B.S.;
(513) 255-5276; AFIT/ENG

Capt Edward Fix, M.S.;
(513) 255-7590; AAMRL/HED

3. DATE: 28 Sep 1988

* Anticonvulsant options: Dilantin (First choice based previous ground based efficacity), Dextromethorphan\Dilantin, Carbamazepine, Dextromethorphan\Carbamazepine

EVALUATION OF THE THERAPEUTIC EFFICACY OF ANTICONVULSANTS IN SPACE MOTION SICKNESS

OPTION 2: MINIMALLY INSTRUMENTED EXPERIMENT

I. Concept

A. Objectives. Investigate the etiology and therapy of space motion sickness on 15 subjects over several space shuttle missions.

1. Explore the etiology of space motion sickness and its relationship to psychomotor/partial seizures. OBJECTIVE MINIMALLY IMPACTED

2. Investigate the use of anticonvulsants in treating and preventing space motion sickness.

3. Investigate the use of new methods, including pattern recognition techniques, in predicting space motion sickness preflight. OBJECTIVE MINIMALLY IMPACTED

4. Identify new parameters to be used in biofeedback techniques. OBJECTIVE MINIMALLY IMPACTED

5. Provide serum samples of alternative biochemical analysis for other investigators of space motion sickness.

B. Experiment Description

1. Subjects. Payload Specialists\Mission Specialists

2. Experimental Technique. Double-blind, Single-blind,or Treat all - To be determined as a function of the mission subjects' availability constraints.

3. Medication.

a. Anticonvulsants

b. Placebo - TBD

4. Apparatus

   a. Silver-silver chloride electrodes

   b. Platinum subdermal electrodes or gold surface electrodes

   c. Respiration tranducers and cabling

   d. One portable data recorders

   e. Miniature centrifuge

   f. Miniature freezer

   g. Hypodermic blood drawing supplies

5. Measurements

   a. One Electrocardiogram (EKG) channel (Lead II)

   b. Four Electroencephalographic (EEG) channels

   c. Two ENG channels

   d. One ESG (EGG) channels

6. Procedure.

   a. Preflight

      (1) Ground based motion sickness evaluations (Coriolis induced motion sickness susceptibility trials).

      (2) Anticonvulsant therapeutic evaluation tests (Coriolis induced motion sickness trials)

         (a) Tolerance to medication

         (b) Absorption rate of medication/serum level determination

         (c) Time course of therapeutic level measurement

         (d) Computerized cognition and performance testing

         (e) Crew procedural training

b. Inflight Requirements

(1) Administer medication (Three options)

(a) Take orally prelaunch and subsequent oral doses inflight

(b) Take orally after symptoms appear and subsequent doses as tolerated.

(c) Take by injection after symptoms appear and subsequent doses as tolerated (A physician should be onboard)

(2) Instrument the subjects on a noninterference basis

(3) Blood collection/processing

(a) Blood sample centrifugation

(b) Blood serum freezing

(4) Monitor physiological parameters on mission days 0 through 3.

(5) Record SMS symptoms in a log book

(6) During post-sleep period

(a) Replace electrodes

(b) Replace data tape

(c) Replace new batteries in the data recorders

c. Post Flight Requirements

(1) Debriefing session

(2) Serum level determination of frozen samples

II. Justification

A. Military Relevance. Space motion sickness is a very expensive disease that affects both NASA and DOD Space Shuttle crew members. Planned crew activites are disrupted when space motion sickness threatens crew safety, crew operations and crew comfort. Consequently, the loss of productive time has cost the space program approximately $10 million per Space Shuttle flight.

1. Crew Safety. Space motion sickness is a potential mortal danger to susceptible astronauts. Astronauts suffering from space motion sickness are

prevented from performing extra vehicular activities. A degradation in their health, such as headaches, malaise, lethargy, nausea, and/or vomiting, increases the danger of an already dangerous situation.

2. **Operations.** This year, NASA personnel reported that 67 percent of the crew members of the first twenty-four Space Shuttle flights reported space motion sickness symptoms. Almost half of the reported 67 percent of space motion sickness cases impacted operations. Space motion sickness has the potential of jeapordizing the success of DOD Inertial Upper Stage missions, free flyer missions (e.g., Air Force Program 888) and sortie missions (e.g., Air Force Program 675 and STARLAB).

3. **Comfort.** The space motion sickness symptoms reported by astronauts are anorexia, headache, malaise, lethargy, general stomach discomfort and vomiting. In severe cases, these symptoms may persist beyond 72 hours. Unfortunately, anti-motion sickness medication has had little success in preventing space motion sickness. Consequently, non-cured crew members must attempt to continue normal operations while suffering from space motion sickness.

B. **Crew Involvement.** Payload Specialist(s) would participate as subjects in the experiment. If agreed, mission specialists could be treated with the medication as well.

C. **Comparison of Alternatives.** The intent is to prevent space motion sickness; therefore, the experiment must be conducted in space.

D. **Cost Estimate and Funding Potential Experiment Maturity.** TBD

E. **Readiness for Flight.** This experiment could be ready by Dec 1989.

MILITARY MAN IN SPACE RESEARCH PROPOSAL

1. TITLE: Evaluation of the Therapeutic Efficacy of *Anticonvulsants in Space Motion Sickness (OPTION 3).

2. Principal Investigators:

William Chelen, M.D. ;
(513) 255-5276; AFIT/ENG

Capt Rogelio Morales, Jr., B.S. ;
(513) 255-5276; AFIT/ENG

Associate Investigators:

Colonel Charles Hatsell, M.D. ;
(513) 255-4649; USAF/MC

Matthew Kabrisky, Ph.D. ;
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Capt Russel Smith, B.S. ;
(513) 255-5276; AFIT/ENG

Capt Edward Fix, M.S. ;
(513) 255-7590; AAMRL/HED

3. DATE: 28 Sep 1988

* Anticonvulsant options: Dilantin (First choice based previous ground based efficacity), Dextromethorphan\Dilantin, Carbamazepine, Dextromethorphan\Carbamazepine

EVALUATION OF THE THERAPEUTIC EFFICACY OF ANTICONVULSANTS IN SPACE MOTION SICKNESS

OPTION 3: NONINSTRUMENTED EXPERIMENT

I. Concept

A. Objectives. Investigate the etiology and therapy of space motion sickness on 15 subjects over several space shuttle missions.

1. Explore the etiology of space motion sickness and its relationship to psychomotor/partial seizures. OBJECTIVE SIGNIFICANTLY IMPACTED

2. Investigate the use of anticonvulsants in treating and preventing space motion sickness.

3 Investigate the use of new methods, including pattern recognition techniques, in predicting space motion sickness preflight. OBJECTIVE MODERATELY IMPACTED

4. Identify new parameters to be used in biofeedback techniques. OBJECTIVE SIGNIFICANTLY IMPACTED

5. Provide serum samples of alternative biochemical analysis for other investigators of space motion sickness.

B. Experiment Description

1. Subjects. Payload Specialists\Mission Specialists

2. Experimental Technique. Double-blind, Single-blind,or Treat all - To be determined as a function of the mission subjects' availability constraints.

3. Medication.

a. Anticonvulsants

b. Placebo - TBD

4. Apparatus

   a. Miniature centrifuge

   b. Miniature freezer

   c. Hypodermic blood drawing supplies

5. Procedure.

   a. Preflight

      (1) Ground based motion sickness evaluations (Coriolis induced motion sickness susceptibility trials).

      (2) Anticonvulsant therapeutic evaluation tests (Coriolis induced motion sickness trials)

         (a) Tolerance to medication

         (b) Absorption rate of medication/serum level determination

         (c) Time course of therapeutic level measurement

         (d) *Computerized cognition and performance testing*

         (e) Crew procedural training

   b. Inflight Requirements

      (1) Administer medication (Three options)

         (a) Take orally prelaunch and subsequent oral doses inflight

         (b) Take orally after symptoms appear and subsequent doses as tolerated.

         (c) Take by injection after symptoms appear and subsequent doses as tolerated (A physician should be onboard)

      (2) Blood collection/processing

         (a) Blood sample centrifugation

         (b) Blood serum freezing

(3) Record SMS symptoms in a log book

c. Post Flight Requirements

(1) Debriefing session

(2) Serum level determination of frozen samples

II. Justification

A. Military Relevance. Space motion sickness is a very expensive disease that affects both NASA and DOD Space Shuttle crew members. Planned crew activites are disrupted when space motion sickness threatens crew safety, crew operations and crew comfort. Consequently, the loss of productive time has cost the space program approximately $10 million per Space Shuttle flight.

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2. Operations. This year, NASA personnel reported that 67 percent of the crew members of the first twenty-four Space Shuttle flights reported space motion sickness symptoms. Almost half of the reported 67 percent of space motion sickness cases impacted operations. Space motion sickness has the potential of jeapordizing the success of DOD Inertial Upper Stage missions, free flyer missions (e.g., Air Force Program 888) and sortie missions (e.g., Air Force Program 675 and STARLAB).

3. Comfort. The space motion sickness symptoms reported by astronauts are anorexia, headache, malaise, lethargy, general stomach discomfort and vomiting. In severe cases, these symptoms may persist beyond 72 hours. Unfortunately, anti-motion sickness medication has had little success in preventing space motion sickness. Consequently, non-cured crew members must attempt to continue normal operations while suffering from space motion sickness.

B. Crew Involvement. Payload Specialist(s) would participate as subjects in the experiment. If agreed, mission specialists could be treated with the medication as well.

C. Comparison of Alternatives. The intent is to prevent space motion sickness; therefore, the experiment must be conducted in space.

(3) Record SMS symptoms in a log book

c. Post Flight Requirements

(1) Debriefing session

(2) Serum level determination of frozen samples

II. Justification

A. Military Relevance. Space motion sickness is a very expensive disease that affects both NASA and DOD Space Shuttle crew members. Planned crew activites are disrupted when space motion sickness threatens crew safety, crew operations and crew comfort. Consequently, the loss of productive time has cost the space program approximately $10 million per Space Shuttle flight.

1. Crew Safety. Space motion sickness is a potential mortal danger to susceptible astronauts. Astronauts suffering from space motion sickness are prevented from performing extra vehicular activities. A degradation in their health, such as headaches, malaise, lethargy, nausea, and/or vomiting, increases the danger of an already dangerous situation.

2. Operations. This year, NASA personnel reported that 67 percent of the crew members of the first twenty-four Space Shuttle flights reported space motion sickness symptoms. Almost half of the reported 67 percent of space motion sickness cases impacted operations. Space motion sickness has the potential of jeapordizing the success of DOD Inertial Upper Stage missions, free flyer missions (e.g., Air Force Program 888) and sortie missions (e.g., Air Force Program 675 and STARLAB).

3. Comfort. The space motion sickness symptoms reported by astronauts are anorexia, headache, malaise, lethargy, general stomach discomfort and vomiting. In severe cases, these symptoms may persist beyond 72 hours. Unfortunately, anti-motion sickness medication has had little success in preventing space motion sickness. Consequently, non-cured crew members must attempt to continue normal operations while suffering from space motion sickness.

B. Crew Involvement. Payload Specialist(s) would participate as subjects in the experiment. If agreed, mission specialists could be treated with the medication as well.

C. Comparison of Alternatives. The intent is to prevent space motion sickness; therefore, the experiment must be conducted in space.

D. Cost Estimate and Funding Potential Experiment Maturity. TBD

E. Readiness for Flight. This experiment could be ready by Nov 1989.

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